JIMMA UNIVERSITY

INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

ENVIRONMENTAL ENGINEERING CHAIR

GEO-CHEMISTRY AND GROUND WATER QUALITY ANALYSIS OF SHEKA ZONE, SOUTHWEST ETHIOPIA

BY

BIZUAYEHU TESFAYE NEGASH (B.Sc.)

A THESIS SUBMITTED TO JIMMA UNIVERSITY INSTITITE OF TECHNOLOGY, FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING IN PARTIAL FULFILLMENT FOR THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL ENGINEERING

JUNE, 2017

JIMMA, ETHIOPIA

JIMMA UNIVERSITY

INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

ENVIRONMENTAL ENGINEERING CHAIR

GEO-CHEMISTRY AND GROUND WATER QUALITY ANALYSIS OF SHEKA ZONE, SOUTHWEST ETHIOPIA

BY

BIZUAYEHU TESFAYE NEGASH (B.Sc.)

MAJOR ADVISOR: - FEKADU FUFA (PhD, Ass. Prof)

CO-ADVISOR:- BINIYAM KEBEDE (M. Sc)

ATHESIS SUBMMITED TO JIMMA UNIVERSITY INSTITIUTE OF TECHNOLOGY, FACULTY OF CIVIL AND ENVIRONMENTAL ENGINNERING IN PARTIAL FULFILLMENT FOR THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL ENGINEERING

JUNE, 2017

JIMMA, ETHIOPIA

Approval sheet

Jimma University Institute of Technology, Faculty of civil and environmental engineering

Department of environmental engineering

Name of the Student: Bizuayehu Tesfaye. Program of Study: M.Sc .in Environmental Engineering

Title: Geo-chemistry and ground water quality analysis of Sheka zone, SNNPR, south west Ethiopia

I declare that the proposed research work has not been done anywhere else before or is not part of any ongoing work.

Name and signature of student; Bizuayehu Tesfaye Sig.__________Date_____/___/____

We have agreed to supervise the proposed research work. We have evaluated the contents of the research and found to be satisfactory, complete and according to the standards and formats of the University. We have also verified that the work has not been done anywhere else before.

Major Advisor: Dr.-Ing Fekadu Fufa (PhD) ____________ ____/_____/__

Name Signature Date

Co-Adviser: Biniyam Kebede (M.Sc) _____________ ____/____/___

Name Signature Date

Decision/suggestion of Department Graduate Council (DGC):-

__________________________________ ____________________ ____/____/___

Chairperson DGC Signature Date

Dedication

I dedicate this work to my family and friends. Thank you so much for your endless prayers and encouragement to hold firm to my dreams.

Declaration

This thesis entitled "Geochemistry and groundwater quality analysis in Sheka zone south western, Ethiopia." has not been presented for a Masters or any other Degree in Jimma Institute of Technology (JIT) or any other university.

Submitted by	--------------------------	--------------------
Bizuayehu Tesfaye	Signature	Date
Researcher		
Approved by	-------------------------	---------------------
Dr. Ing.- Fekadu Fufa	Signature	Date
Main Advisor		
Mr. Biniam Kebede	-------------------------	---------------------
Co-advisor	Signature	Date
Dr. Dejene Beyene	-------------------------	---------------------
Chair Holder	signature	Date

Abstract

Groundwater refers to all the water occupying the voids, pores and fissures within earth and its source will be various strata of the earth crust. The current concern of world is the issues of water quality binding with human and environmental health that will focus on problem of different chemical contaminants. The study was conducted on ground water of Sheka Zone; SNNPR, South-Western Ethiopia. Thirteen ground water samples were collected from different sampling points. Field and laboratory based measurement was conducted to determine concentration of cations and an anion in water. Suitability of water for drinking was determined by cation and anion measurement followed by comparing with WHO GVs. SAR, SSP, RSC, MH and KR analysis were conducted to evaluate suitability of water for irrigation. Water type of the study area was determined by using AQUACHEM V.4 software that develops piper diagram. The result indicates that; all water samples had pH value between 6.5 and 7.5, which is below WHO standard. The EC of sampled water is below WHO standard (250 NTU). TDS of water is below the GV (<500 mg/L) and it is fine while Temperature of four sampled water is above WHO GV. Nitrate concentration in one hand dug well in Masha Woreda was raised with value of 11.4 mg/L. Calcium ion concentration is between 5.8 mg/L and 32.70 mg/L, Magnesium ion ranges from 1.02 to 3.41 mg/L. Average concentration of Sodium ion is 4.04 mg/L. Six water samples had Iron concentration above WHO GV (0.3 mg/L) with maximum concentration of (1.72 mg/L) in hand dug well of Masha Woreda. Five water samples exhibited high concentration of Manganese above WHO GV (0.4 mg/L). Maximum Manganese concentration (1.92 mg/L) is recorded in hand dug well of Masha town. Alkaline earth metals dominate the hydrological face of water in the study area. Generally, water type of area is Ca-HCO_3-SO_4. Except two water samples with SSP value >60, almost all water are suitable for irrigation use. SAR value of all water samples indicates; the water is safe for irrigation. MR value of 12 water samples indicate <50 and this confirms the suitability of water for irrigation use. Generally, it is possible to use ground water of Sheka zone for drinking with minor treatment alternatives and fully possible to use for irrigation purpose.

Key words: *Ground water, Water type, Chemical composition, SAR.*

Acknowledgments

I would like to thank Heart fully the Ethiopia Road Authority (ERA) for proving me a golden opportunity to pursue my MSc Degree in Environmental Engineering. The Authority supported me by all financial cover for education expense which will be untouchable to go on it personally.

I am very glad to my major advisor Dr. Fekadu Fuffa (PhD, Ass. Prof.) who advised me so closely starting from the development of this thesis, I would like to thank him for directing me to the most important aspects of the topic and drawing up my attention in several parts of the developing the structure and whole contents of this document. His comments were so perceptive, helpful, and appropriate.

I would like to thank my co-advisor, Mr. Biniyam Kebede (M.Sc.) for his valuable guidance, kindness, encouragement, and constructive criticisms

I would like to thank also Jimma University Institute of Technology especially Environmental Engineering chair for creating a good learning Environment while learning and research work.

Table of contents

List of Tables

List of Figures

List of Abbreviations

APHA	American Public Health Association
BCM	Billion Cubic Meter
DBSPM	N, N´-bis (3-benzylaminopropyl) butane-1, 4-diamine
DO	Dissolved Oxygen
EC	Electrical Conductivity
EPA	Environmental Protection Agency
FMoWR	Federal Ministry of Water Resource
GPS	Global Positioning System
GV	Guideline Value
GW	Ground Water
IBE	Ion Balance Error
JECFA	Joint FAO/WHO Expert Committee on Food Additives
KR	Kelley's Ratio
m.a.s.l	Meter above sea level
mg/L	Milligram per litter
MH	Magnesium Hazard
MMT	Methylcyclopentadienyl manganese tricarbonyl
NGOs	Non-Governmental Organizations
NTU	Nephelometric Turbidity Units
ORP	Oxidation-Reduction Potential

OWWDSE	Oromia Water Works Design and Supervision Enterprise
PMTDI	Provisional maximum tolerable daily intake
RSC	Residual Sodium Carbonate
SAR	Sodium Adsorption Ratio
SSP	Soluble Sodium Percentage
SNNPR	Southern Nations Nationalities Peoples Republic
TA	Total Alkalinity
TDS	Total Dissolved Solids
TH	Total Hardness
UNEP	United Nations Environment Program
UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organization
μS/cm	Micro Siemens per centimeter

CHAPTER ONE

1. Introduction

1.1. Background

Groundwater refers to all the water occupying the voids, pores and fissures within geological formations, which originated from atmospheric precipitation either directly by rainfall infiltration or indirectly from rivers, lakes or canals. Usually the source of ground water supply are sands, gravel, sandstones, and limestone formations and some may be drawn from impervious rocks such as granite when they have an over burden of sand or gravel (Olumuyiwa *et al*., 2012).It is well known that about two third or 70% the earth planet is covered by water body and groundwater beneath the sub surface in the aquifers accounts 1.7% (Brindha *et al*., 2011). The utilization of groundwater has been increasing due to changes in natural and human activities; the increasing water demand has triggered the alteration of water quality by various factors including geological and anthropogenic sources (Saravanan *et al*., 2015). Groundwater is extensively exploited on the world and this exploitation is more rapid in arid and semi-arid zones of the world. The most determining factor for prior utilization of ground water is its quality. Quality of groundwater is deteriorated in many geographical regions due to natural processes and human interventions (Sajil *et al*., 2014).

Worldwide water is drawn from the ground for a variety of uses, principally community water supply, farming (both livestock and irrigated cultivation), industrial processes and for other utilities (Chilton, 1996) but presence of low or high concentration of certain ions is a major issue as they make the groundwater unsuitable for various purposes (Brindha and Elango, 2011). In Africa and Asia, most of the largest cities use surface water, but many millions of people in the rural areas are dependent on groundwater. For many millions more, particularly in sub- Saharan Africa, who do not as yet have any form of improved supply, untreated groundwater supplies from protected wells with hand pumps are likely to be their best solution for many years to come (Chilton, 1996).

The quality of ground water sources are affected by the characteristics of the media through which the water passes on its way to the ground water zone of saturation (Adeyemi *et al*., 2006). Shortages of water in Africa is often due to problems of uneven distribution sometimes there is much water where there are fewer people - and also to management of existing supplies that could be improved (John, 2002).

The written fact by John Newby also tells us that fourteen countries in Africa are already experiencing water stress; another 11 countries are expected to join them by 2025 at which time nearly 50 per cent of Africa's predicted population of 1.45 billion people will face water stress or scarcity for future. He again stated that nearly 51 per cent (300 million people) in sub-Saharan countries lack access to a supply of safe water and 41% lack adequate sanitation. According to review on ground water availability and fair use of this resource, over 15 Sub-Saharan Africa countries, it is challenging task of the era similarly facing all over the world.

Sub-Sahara African countries have fusion rich and poor resource but are generally underutilizing their available water resources, including groundwater. Most of the countries in the region have agriculture as their primary source of livelihoods and an entrenched dependence on wells and boreholes for the provision of rural water supplies (Paul *et al*., 2012). In Sub-Saharan Africa, the Eastern African region, particularly the Horn of Africa, is considered highly geographically exposed to climate change and its impact over water. About 70 million people in this area are located in areas prone to extreme drought leading to water insecurity and food shortages. In this Eastern African region, floods and droughts can occur in the same area within a very short period. Such events can exacerbate water availability in quality and quantity, sufficient enough to sustain agricultural activities and energy production (Ndaruzaniye, 2011).

Ethiopia a country with complicated hydro geological environment and complex groundwater regime, has 12 river basins with an annual runoff volume of 122 billion m^3 of water and an estimated 2.6 - 6.5 billion m^3 of ground water potential, which makes an average of 1575 m^3 of physically available water per person per year, a relatively large volume. However, due to lack of water storage infrastructure and large spatial and temporal variations in rainfall, there is not enough water for most farmers to produce more than one crop per year (Sileshi *et al*., 2007).

Ethiopia as a second popular country in Africa, most or 85% of the population lives in rural areas where water shortage is more predominating problems. This shortage of water can be solved by proper utilization of groundwater and first attempt to identify the main aquifers in various parts of Ethiopia, identifying geo-petro graphical environments and variable climate, which will be very important in giving proper solution for water supply problems in arid and semi aid part of the country (Tamiru, 2006).

In Ethiopia, several studies on ground water potential assessments indicate the rechargeable or replenish able ground water potential of the country is in the order of 2.6 billion cubic meters (BCM). More recent emerging studies and implementations like that of Addis Ababa, Kobo and Raya well field indicate the potential is far greater. Estimations of the ground water require a good understanding of the regional geology, hydrology, hydrogeology, hydraulics of ground water flow (Semu, 2012). The occurrence of groundwater in Ethiopia is mainly influenced by the geology, geomorphology, tectonics and climate of the country. The geology of a given place provides usable groundwater and provides good transmission of rainfall to recharge aquifers, which produce springs and feed perennial rivers (Tamiru, 2006).

One of the most common environmental issues today is ground water contamination and diversity of contaminants that affecting water resources (Vadila *et al*., 1997). In Ethiopia, high concentrations of iron were found in the groundwater supplies of Addis Ababa, Afar, Amhara, Benshangul, Gambella, Western Oromiya and SNNPR (FMoWR, 2000; 2001), and high iron concentrations commonly cause consumers to reject ground water supplied for drinking. Ground water of Chelelektu and Yirgachefe towns of Gedio zone, Sidama, Bench Maji, Kaffa and Sheka zones of SNNPR (FMoWR, 2000; 2001). The problem is so severe at Chelelektu and Yirgachefe towns that iron removal plants had to be installed (WHO and UNICEF, 2010). But there has been no study indicating the concentration of different cation and anion in the ground water of Sheka zone, Southern Ethiopia.

1.2. Statement of the Problem

The recent concern of world is the issue of quality of water and health of environment focusing on chemical contamination which has been seen as a major treat for environmental and human health because of their toxicity. Potable water is a necessary and limited resource that humans need for daily activities (Silderberg, 2003).

In Sheka zone, most of the community has their own hand dug well at their provinces. Different NGOs and Government constructed hand dug wells and deep wells for communities. The constructed water schemes have been used for drinking, food preparation, bathing, for industrial purpose (Coffee processing), for small scale irrigation, and for livestock. Except few deep wells which were constructed by SNNPR Water, Mineral and Irrigation Bureau, no chemical analysis was performed for most water schemes. Community of the study area has been using the water which is not tested and chemically analyzed. Even though it is stated on WHO and UNICEF 2010 report that Sheka zone has high concentration of Iron in its ground water, no study has been conducted to address this issue. Therefore it is important to conduct study in Sheka zone which performs evaluation and analysis of physico chemical and chemical content of ground water.

1.3. Objective of the study

1.3.1. General Objective

- To determine and evaluate the geochemical composition of groundwater of the Sheka zone.

1.3.2. Specific Objectives

1) To determine the suitability of the groundwater for drinking purposes.
2) To analyze the chemical compositions of the ground water for irrigation purposes
3) To identify the geochemical processes that causes change in the water quality
4) To determine water type of the study area

1.4. Research questions

1) What are the major physicochemical constituents of the groundwater?
2) What is the current status of groundwater quality standard in accordance with WHO standard for drinking purpose?
3) What are the major chemical constituents of ground water in the study area?
4) Does the groundwater fit the precondition irrigation water use and is that suitable for irrigation uses?

1.5. Significance of the study

Knowledge of ground water quality can provide important insight in to the nature of resource. Evaluation of the natural chemical and isotopic compositions of ground water can provide inferences of the reaction that produce natural water chemistry and the recharge, movement, mixing and discharge of ground water. People to exist on the earth surly needs water priority giving to drinking of potable and palatable water from whatever the source is. It is also fact that basic sanitation and hygiene is crucial need of people. Food which is going to be delivered to children and generally for human being has to be prepared and processed by clean and potable water. World Health Organization (WHO) has a guide line permissible limit to use of water for different activities to keep human health and environment. Therefore there is a need for assessment of geochemical quality of water.

This study was initiated to determine the quality in relation to chemical composition of ground water for which it is intended to use. It is also important to identify major geochemical processes that cause change in quality of the water. The results of this study will provide baseline information on the profile of geological patterns and water quality deteriorating factors.

1.6. Limitation of the study

The study did not fully cover the entire districts in Sheka Zone. The main reason for this is the constraints of budget and limitation of time. The study is also a cross-sectional study type in which samples were collected only in a single rainy season because of limitation of time and resources. The parameters assessed in this study are also specific and selected i.e. there were no complete assessment of all water quality parameters rather than we focused on major components. A difficulty was faced in obtaining depth and other geological profiles for water wells. Since sample collection period was in a wet season, it needs dry season assessment in order to reduce the problem of seasonal variability. But the research focused to obtain the necessary data and information during the entire study period with maximum effort.

CHAPTER TWO

2. Literature Review

2.1. Ground water quality and chemistry

In the era of blooming industries and technologies with accelerated world population growth, the necessity and water with both quantity and quality aspect is very crucial and basic need for us. In contrast to this fact now day water pollution is one of the most dangerous challenges what our plant has been facing (Vodela *et al*., 1997). The quality of ground water depends on its purpose; thus needs for drinking, institutions, industries and irrigation use. Natural ground water generally acquires dissolved constituents by dissolution of aquifer gasses, minerals and salt. Consequently, soil zone and aquifer gas and the most soluble minerals in aquifer generally determine the chemical composition of ground water in aquifer (David and Lary, 2005).

The chemical quality of groundwater can influence the chemical composition of soils and rocks through which the water flows, depending upon the mineral dissolution, mineral solubility, ion exchange, oxidation, reduction etc. (Rao *et al*., 2011). Chemical analysis of groundwater includes the determination of the concentrations of inorganic substances including metallic constituents, pH and electrical conductance. The parameter determined under physical analysis methods also includes measurement of temperature, color, turbidity, odor and taste (Olumuyiwa *et al*., 2012).

Knowing the general properties of natural ground water quality is important to provide decisive nature of the water resource. Evaluation of the natural chemical and isotopic composition of ground water can provide inferences of the reaction that produce natural ground water chemistry (David and Lary, 2005). Calcium and Magnesium which will be present in water in different constituents can play a substantial role in determining chemical water quality. The higher contribution of Mg^{2+}than that of the contribution of Ca^{2+} is caused by the influences of ferromagnetism minerals, ion exchange between Na^{+} and Ca^{2+}, precipitation of $CaCO_3$, and marine environment. The concentration of Na^{+} is varied from 192 to 453 mg/L in a general case. The higher contribution of Na^{+} than that of the contribution of Ca^{2+} to the total cation is expected due to influence of ion exchange (Rao *et al*., 2011). In fact, the Cl^{-} is derived mainly from the non-litho logical source and its solubility is generally high. Moderate concentration of Cl^{-}anions in the groundwater, is caused by the influences of poor sanitary conditions, irrigation-return flows and chemical fertilizers, and no other sources are evident (Rao *et al*., 2011).

The sources of geogenic (apatite, biotite, and clays) and anthropogenic (chemical fertilizers), with a combination of higher rate of evaporation and longer interaction of water with the aquifer materials under alkaline environment, are the key factors for the concentration of F^{-}. NO_3^{-} is a non-lithological source. In natural conditions, the concentration of NO_3^{-} does not exceed 10 mg/L in the water so that the higher concentration of NO_3^{-}, beyond 10 mg/L, is an indication of anthropogenic pollution (Cushing *et al*., 1973). The concentration of bicarbonate in ground water is determined by natural geological formation of an area. Mainly amount of bicarbonate will be low in areas where marine clay occurs (Rao *et al*.,2011).

2.2. Physico-chemical aspect of water quality

In 1995, WHO described the meaning of physico-chemical as; quality which is used in reference to the characteristics of water which may affect its portability and palatability due to aesthetic considerations. The odor of substance can also influence temperature because of relationship between odor and vapor pressure, therefore odor measurement usually specify temperature (Olumuyiwa *et al*., 2012).

2.2.1. pH

p^{H} influences the taste and odor of a substance significantly, especially when it controls the equilibrium concentration of the neutral and ionized forms of a substance in solution (Olumuyiwa *et al.*,2012). Strength of water to react with acidic or alkaline materials present it can be determined by p^{H} (Rao *et al*., 2011).

No health-based guideline value is proposed for pH. Although pH usually has no direct impact on consumers. It is one of the most important operational water quality parameters. The optimum pH required often being in the range 6.5–9.5 (WHO, 2006).

When pH of water exceeds the maximum permissible limit (8.5), it cause Rusting and causes cancer (WHO, 1997).

2.2.2. Temperature

The temperature of water to a large extent determines the extent of microbial activity. Temperature is the measure of hotness or coldness of water measured either in degree Celsius or Fahrenheit by using a thermometer (APHA, 1985). When temperature of water becomes above 25°C, it will cause bone disease (pain and tenderness of) children may get (WHO, 1997).

2.2.3. Total Dissolved Solids (TDS)

TDS is a measure of salinity that can have an important effect on the taste of drinking-water. The palatability of water with a TDS level of less than 600 mg/L is generally considered to be good; drinking water becomes significantly unpalatable at TDS levels greater than 1000 mg/L (UNICEF, 2008). TDS comprise of organic matter and inorganic salts, which may originate from sources such as sewage, effluent discharge and urban run-off or from natural bicarbonates, chlorides, sulfate, nitrate, sodium, potassium, calcium and magnesium (WHO, 2006).Concentrations of TDS in water vary considerably in different geological regions owing to differences in the solubility of minerals. However, the presence of high levels of TDS in drinking-water (greater than 1200 mg/L) may be objectionable to consumers. Water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste (WHO, 2006). TDS is related to other water quality parameters like hardness, which may occur if the high TDS content is due to the presence of carbonates (Olumuyiwa *et al*., 2012).

Taste and odor of water depend on the stimulation of the human receptor cells, which are located in the taste-buds for taste and nasal cavity for odor (WHO, 1984). Taste and odor problems account for the largest single class of consumer complaints in drinking water supplies, due to the water source, the treatment method, distribution system or a combination of all three (WHO,1984). Water with TDS value above 1000mg/L can cause stomach discomfort (WHO, 1997).

2.2.4. Turbidity

Turbidity adversely affects the efficiency of disinfection of water. It is measured to determine what type and level of treatment are needed. It can be carried out with a simple turbidity tube that allows a direct reading in nephelometric turbidity units (NTU) (WHO, 2006). Turbidity in drinking-water is caused by particulate matter that may be present from source water as a consequence of inadequate filtration or from resuspension of sediment in the distribution system. It may also be due to the presence of inorganic particulate matter in some groundwater or sloughing of biofilm within the distribution system. The appearance of water with a turbidity of less than 5 NTU is usually acceptable to consumers, although this may vary with local circumstances. No health-based guideline value for turbidity has been proposed; ideally, however, median turbidity should be below 0.1 NTU for effective disinfection, and changes in turbidity are an important process control parameter (WHO, 2006). Water with elevated turbidity will cause nausea, cramps, diarrhea and associated head ache (WHO, 1997).

2.2.5. Electrical Conductivity (EC)

Conductivity is the measure of capacity of a substance to conduct the electric current. Most of the salts in water are present in their ionic forms and capable of conducting current and conductivity is a good indicator to assess groundwater quality. EC is an indication of the concentration of total dissolved solids and major ions in a given water body. It is temperature dependent and the international unit is Siemens per meter (Hounslow, 1995; Mazor, 1991). When the Electrical Conductivity value of water becomes larger; Anemia; liver kidney or spleen damage; changes in blood will occur in the body of consumers (WHO, 1997).

2.3. Major chemical components detonating water quality

2.3.1. Iron (Fe)

Heavy metals like iron, found in natural water bodies occur at varying concentrations and are usually monitored by measuring their concentrations in water, sediment and biota (Kalu *et al*., 2015).Some of these metals are vital to keep up life such as Calcium, Magnesium, Potassium and Sodium, which are necessary for common body functions and others including Cobalt, Copper, Iron, Manganese, Molybdenum and in is needed at low level as catalyst for enzyme activities (Meghdad *et al*., 2013). However when the concentrations of these metals exceeds the maximum permissible level or standard value, it becomes highly toxic to human health and environment. It also causes malfunctioning of enzymatic activities (Meghdad *et al*., 2013).

The use of groundwater for drinking is in many cases limited by the presence of dissolved iron and to a lesser extent manganese. These give the water an unpleasant metallic taste and stain food, sanitary ware and laundry. Iron with concentration value greater than 0.3 mg/L can causes rusting and cancer (WHO, 2004). Dissolved iron in ground water is controlled by pH and redox conditions and is dependent on iron-bearing minerals in the aquifer (Eric *et al*., 2003).

Iron is one of the most abundant metals in the Earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/L. Iron may also be present in drinking-water as a result of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution. Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status and iron bioavailability and range from about 10 to 50mg/day (WHO, 2006).

The history of standard guideline development for concentration of Iron in water suggest in 1985 that, Iron concentration greater than 1.0 mg/L would markedly impair the suitability of the water and deteriorate the water quality. The 1963 and 1971 International Standards retained this value as a maximum allowable or permissible concentration. In the "first edition of the Guidelines for drinking-water Quality", published in 1984, a guideline value of 0.3 mg/L was established, as a compromise between iron's use in water treatment and aesthetic considerations. Iron stains laundry and plumbing fixtures at levels above 0.3 mg/L. There is usually no noticeable taste at iron concentrations below 0.3 mg/L (WHO, 2006). When the iron concentration of the water is above 0.3 mg/L, rusting, the probability of occurrence cancer is great (WHO, 1997).

2.3.2. Manganese (Mn)

Manganese is one of the most abundant metals in the Earth's crust. It is used principally in the manufacture of iron and steel alloys, as an oxidant for cleaning, bleaching and disinfection as potassium permanganate and as an ingredient in various products. More recently, it has been used in an organic compound, Methylcyclopentadienyl manganese tricarbonyl (MMT), as an octane enhancer in petrol in North America. Manganese greensands are used in some locations for potable water treatment. Manganese is an essential element for humans and other animals and occurs naturally in many food sources. The most important oxidative states for the environment and biology are Mn^{2+}, Mn^{4+} and Mn^{7+}. Manganese is naturally occurring in many surface water and groundwater sources, particularly in anaerobic or low oxidation conditions, and this is the most important source for drinking water. The greatest exposure to manganese is usually from food. Manganese usually occurs in fresh water with typically level range from 1 to 200 mg/L, although levels as high as 10 mg/L in acidic groundwater have been reported; higher levels in aerobic waters usually associated with industrial pollution. The WHO standard guide line value for Manganese is 0.4 mg/L (WHO, 2006).

2.3.3. Calcium (Ca)

Calcium is one constituent of "Hardness" in water and not a hazard to health. Calcium is undesirable because it may be detrimental for household use such as washing, bathing and laundering. It also tends to cause encrustation in kettles, coffee makers and water heaters and may impair treatment processes (Zodape *et al*., 2013). When the concentration of calcium in drinking water is above 200mg/L, it will cause indigestibility of fat in the body (WHO, 1997).

2.3.4. Sodium (Na^+)

Although concentrations of sodium in potable water are typically less than 20 mg/L, they can greatly exceed this in some countries. The levels of sodium salts in air are normally low in relation to those in food or water. It should be noted that some water softeners can add significantly to the sodium content of drinking-water. No firm conclusions can be drawn concerning the possible association between sodium in drinking-water and the occurrence of hypertension. Therefore, no health based guideline value is proposed. However, concentrations in excess of 200 mg/L may give rise to unacceptable taste (WHO, 2006).

Sodium in the human body helps in maintaining the amount of water balance. Human intake of sodium is mainly influenced by the consumption of sodium as chloride or table salt. The treatment for certain heart condition, circulatory or kidney diseases or cirrhosis of liver may include sodium restrictions. Diets for these people should be designed with the sodium content of their drinking water taken in to account. The recommended maximum level for people suffering from certain medical conditions such as hypertensions, congestive heart failure or heart disease is 20 mg/L (Zodape *et al*., 2013). Water with sodium concentration above 200 mg/L increased the risk of cancer (WHO, 1997).

2.3.5. Potassium (K)

Potassium is an essential element in humans and occurs widely in the environment, including all natural waters. The primary source of potassium for the general population is the diet, as potassium is found in all foods, particularly vegetables and fruits. Some food additives are also potassium salts like potassium iodide and it is also rarely occur in drinking water a level that could be a concern for healthy humans (Zodape *et al*., 2013). However the contamination of drinking water by potassium can occur due to the use of excessive potassium permanganate as an oxidant in water treatment and due to the consumption of water obtained from water softeners that uses potassium chloride (Zodape *et al*., 2013). Potassium is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for healthy humans. Potassium occurs widely in the environment, including all natural waters and it can also occur in drinking-water as a consequence of the use of potassium permanganate as an oxidant in water treatment (WHO, 2009). When the concentration of potassium in drinking water becomes above 50mg/L, there will be effect on blood pressure of consumers (WHO, 1997).

2.3.6. Chloride (Cl^-)

Chloride in drinking water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion. The main source of human exposure to chloride is the addition of salt to food, and the intake from this source is usually greatly in excess of that from drinking-water. Elevated concentration of chloride in increases the rates of metallic corrosion in water distribution system even though it depends on the alkalinity of the water. This can lead to increased concentrations of metals in the supply. No health-based guideline value is proposed for chloride in drinking-water. However, chloride concentrations in excess of about 250 mg/L can give rise to detectable taste in water (WHO, 2006).

2.3.7. Alkalinity

Alkalinity is primarily composed of carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) alkalinity that can turn as stabilizer for p^H. The nature and toxicity of water from different sources of can be affected by Alkalinity, pH and hardness substances found within it. The Alkalinity nature of water can be determined by the presence of one or more ions in water including hydroxides, carbonates, and bicarbonates. It is usually expressed as the capacity to neutralize acid. To prevent corrosive effect of acidity in drinking water supply system it is anticipated to have moderate concentration of alkalinity. Unbalanced and excessive quantities alkalinity of water may cause a number of damages. The WHO standards express the alkalinity only in terms of total dissolved solids (TDS) of 500 mg/L (Muhammad *et al*., 2013).

2.3.8. Nitrate

Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. Nitrate is used mainly in inorganic fertilizers, and sodium nitrite is used as a food preservative, especially in cured meats. The nitrate concentration in groundwater and surface water is normally low but can reach high levels as a result of leaching or runoff from agricultural land or contamination from human or animal wastes as a consequence of the oxidation of ammonia and similar sources. The formation of persistence of nitrite will be due to anaerobic environment. Chloramination may give rise to the formation of nitrite within the distribution system if the formation of chloramines is not sufficiently controlled. The formation of nitrite is as a consequence of microbial activity and may be intermittent. Nitrification in distribution systems can increase nitrite levels, usually by 0.2–1.5 mg/L. Guide line value for nitrate is 50 mg/L to protect against methaemoglobinaemia in bottle-fed nitrate infants (WHO, 2006).

2.3.9. Magnesium (Mg)

Magnesium arises mainly from the weathering of rocks having ferromagnetism minerals and from some carbonate rocks. It can occur in several organ metallic compounds and in organic matter as it is vital element for living organisms.

Magnesium occurs normally in dark colored minerals present in igneous rocks such as plagioclase, pyroxenes, amphiboles, and the dark colored micas. It can also found as a constituent of chlorite and serpentine in metamorphous rocks (Perk, 2006). Magnesium is common in natural waters as Mg^{2+}, and along with calcium, is a main contributor to water hardness. In natural fresh water the concentrations of magnesium may range from 1 to 100 mg/L (UNICEF, 2008). When the concentration of magnesium in drinking water is above the permitted limit, Gastro intestinal, liver or kidney damage will occur over consuming community (WHO, 1997).

2.3.10. Sulfate

Sulfates occur naturally in numerous minerals and are used commercially, principally in the chemical industry. They are discharged into water in industrial wastes and through atmospheric deposition; however, the highest levels usually occur in groundwater and are from natural sources. In general, the average daily intake of sulfate from drinking-water, air and food is approximately 500mg, food being the major source. However, in areas with drinking-water supplies containing high levels of sulfate, drinking-water may constitute the principal source of intake (WHO, 2006).

Sulfate is also a combination of sulfur and oxygen. It occurs naturally in many soil and rock formations. In groundwater, most sulfates are generated from the dissolution of minerals, such as gypsum and anhydrite. Saltwater intrusion and acid rock drainage are also sources of Sulfates in drinking water. Manmade sources include industrial discharge and deposition from burning of fossil fuels (WHO, 2011). Sulfate concentrations in natural waters are usually between 2 and 80 mg/L. High concentrations greater than 400 mg/L may make water unpleasant to drink (UNICEF, 2008). When the concentration of sulfate in drinking water is above 400mg/L allergic dermatitis problem can occur on the consumer (WHO, 1997).

2.3.11. Total Hardness (Ca and Mg)

Hardness in water is caused by dissolved calcium and to a lesser extent magnesium. It is usually expressed as the equivalent quantity of calcium carbonate. Depending on pH and alkalinity, hardness above 200 mg/L can result in scale deposition particularly on heating. Soft waters with a hardness of less than 100 mg/L have a low buffering capacity and may be more corrosive to water pipes. A number of ecological and analytical epidemiological studies have shown a statistically significant inverse relationship between hardness of drinking-water and cardiovascular disease (WHO, 2006).

There is some indication that very soft waters may have an adverse effect on mineral balance, but detailed studies were not available for evaluation. No health-based guideline value is proposed for hardness. However, the degree of hardness in water may affect its acceptability to the consumer in terms of taste and scale deposition (WHO, 2006). Public acceptability of the degree of hardness may vary considerably from one community to another, depending on local conditions, and the taste of water with hardness in excess of 500 mg/L is tolerated by consumers in some instances (WHO, 2006).

Hardness caused by calcium and magnesium is usually indicated by precipitation of soap scum and the need for excess use of soap to achieve cleaning. Public acceptability of the degree of hardness of water may vary considerably from one community to another, depending on local conditions. In particular, consumers are likely to notice changes in hardness (WHO, 2006).

The taste threshold for the calcium ion is in the range of 100–300 mg/L, depending on the associated anion, and the taste threshold for magnesium is probably lower than that for calcium. In some instances, consumers tolerate water hardness in excess of 500 mg/L. Depending on the interaction of other factors, such as pH and alkalinity, water with hardness above approximately 200 mg/L may cause scale deposition in the treatment works, distribution system and pipework and tanks within buildings. It will also result in excessive soap consumption and subsequent "scum" formation. On heating, hard waters form deposits of calcium carbonate scale. Soft water, with a hardness of less than 100 mg/L, may, on the other hand, have a low buffering capacity and so be more corrosive for water pipes. No health-based guideline value is proposed for hardness in drinking-water (WHO, 2006).

Hardness in water is caused primarily by the presence of carbonates and bicarbonates of calcium and magnesium, Sulfate, chlorides and nitrates. The hardness of natural waters depends mainly on the presence of dissolved calcium and magnesium salts. The total content of these salts is known as general hardness, which can be further divided into carbonate hardness (determined by concentrations of calcium and magnesium hydro carbonates), and non-carbonate hardness (determined by calcium and magnesium salts of strong acids). The total hardness of water classified in to three ranges (0-300 mg/L, 300-600 mg/L and > 600 mg/L) low, medium and high respectively (Karthikeyan *et al.*, 2013). When the total hardness of drinking water exceed 500 mg/L increase in blood pressure of consuming community will occur (WHO, 1997).

2.4. Suitability of water for irrigation purpose

The source of water we used for irrigation will be springs, streams, or pumped water from rivers or from deep wells. These sources of water will contain considerable amounts of chemical substances in solution form and it may diminish crop yield and worsen soil fertility. These substances may vary in a wide range, but mainly consist of dirt and suspended solids resulting into the emitters' blockages in micro-irrigation systems and bacteria populations and coli forms harmful to the plants, humans and animals (Ayers, 1976). The most damaging effects of poor-quality irrigation water are excessive accumulation of soluble salts and/or sodium in soil. Highly soluble salts in the soil make soil moisture more difficult for plants to extract, and crops become water stressed even when the soil is moist. When excessive sodium accumulates in the soil, it causes clay and humus particles to float into and plug up large soil pores. This plugging action reduces water movement into and through the soil, thus crop roots do not get enough water even though water may be standing on the soil surface (Zhang, 1990). Groundwater quality comprises the physical, chemical and biological qualities of groundwater. Temperature, turbidity, color, taste and odor make up the list of physical water quality parameters. Since most groundwater is colorless, odorless and has no specific taste, we are typically more concerned with its chemical qualities (Harter, 2003).

Table 2.1: Classification of irrigation water based on Electrical Conductivity (Richards, 1954)

Water Class	**EC (micro mhos/cm)**	**Salinity Significance**
Excellent	<250	Water of low salinity is generally composed of higher proportions of calcium, magnesium and bicarbonate ions.
Good	250-750	Moderately saline water, having varying ionic Concentrations
Permissible	750-2250	High saline waters consist mostly of sodium and chloride Ions
Doubtful	>2250	Water containing high concentration of sodium, bicarbonate and carbonate ions have high pH

2.5. Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio (SAR) is a measure of the suitability of water for irrigation use, because sodium concentration can reduce the soil permeability and soil structure (Todd, 1980). SAR is a measure of alkali/sodium hazard to crops and it was estimated by the following formula:

$$\boldsymbol{SAR} = \frac{[\boldsymbol{Na^{+}}]}{\sqrt{\frac{[\boldsymbol{Ca^{2+}+Mg^{2+}}]}{\boldsymbol{2}}}} \qquad \text{---(2.1)}$$

Where $[Na^{+}]$, $[Ca^{2+}]$ and $[Mg^{2+}]$ are concentration of sodium, calcium and magnesium in meq/L respectively.

The SAR value of water for irrigation purposes has a significant relationship with the extent to which sodium is absorbed by the soils. Irrigation using water with high SAR values may require soil amendments to prevent long-term damage to the soil, because the sodium in the water can displace the calcium and magnesium in the soil. This will cause a decrease in the ability of the soil to form stable aggregates and loss of soil structure. This will also lead to a decrease in infiltration and permeability of the soil to water leading to problems with crop production.

Table 2.2: Irrigation water classification based on SAR (Richards, 1954)

SAR	**Water class**
Less than 10	Excellent
10 to 18	Good
18 to 26	Permissible
More than 26	Unsuitable

2.6. Soluble sodium percentage (SSP)

Wilcox in 1948 used percentage sodium and electrical conductance in evaluating the suitability of groundwater for irrigation. The percentage of sodium is computed with respect to the relative proportions of cations present in water, where the concentrations of ions are expressed in meq/L using the formula as shown below.

$$\%Na = \frac{[Na^{+}+K^{+}]}{[Ca^{2+}+Mg^{2+}+Na^{+}+K^{+}]}$$ --(2.2)

Excess Na^{+}, combining with carbonate, leads to formation of alkali soils, whereas with chloride, saline soils are formed. Neither soil will support plant growth (Rao, 2006). Generally, percent of Na^{+} should not exceed 60 % in waters intended for irrigation purpose.

Table2.3: Classification of irrigation water based on SSP (Wilcox, 1955)

SSP	**Water class**
< 20	Excellent
20 – 40	Good
40 – 60	Permissible
60 – 80	Doubtful
>80	Unsuitable

2.7. Residual Sodium Carbonate (RSC)

The quality of water for irrigation purpose in accordance with carbonate containment can be calculated to determine the hazardous effect of CO_3^{2-} and HCO_3^{-} on the quality and suitability of water (Eaton, 1950).

The RSC value was calculated using the formula given below.

$$RSC = [CO_3^{2-} + HCO_3^{-}] - [Ca^{2+} + Mg^{2+}]$$ --------------------- (2.3)

Where, all the ionic concentrations of the elements are expressed in meq/L.

RSC <1.25 are safe for irrigation; it is considered as unsuitable if it is greater than 2.5. The high RSC value in water leads to precipitation of Ca^{2+} and Mg^{2+} (Raghunath, 1987). As a result, the relative proportion of sodium in the water is increased in the form of sodium bicarbonate (Sadashivaiah *et al*., 2008). The higher concentration of RSC causes the soil structure to deteriorate, the movement of air and water through the soil is restricted; soil alkalinity increases and plant growth is shunted (Reddy, 2011).

Table2.4: Suitability of groundwater for irrigation according to RSC value

Class	Quality	Hazard
<0	Very good quality	None
0-1.25	Water of good quality, used for irrigation of all soils.	Low, with some removal of calcium and magnesium from irrigation water.
1.25-2.5	Water of medium quality used in case of good drainage especially with calcium.	Medium, with appreciable removal of calcium and magnesium from irrigation water.
>2.5	Unsuitable water, especially in poor drainage or when soluble calcium.	High, with most calcium and magnesium removed leaving sodium to accumulate.

2.8. Kelley's Ratio (KR)

Sodium related problem in irrigation water could scientifically be explained and performed by Kelley's ratio and it was suggested by (Kelley *et al.*, 1940).

Groundwater which has Kelley's ratio greater than one is generally considered as unfit for irrigation.

$$KR = \frac{[Na^{+}]}{[Ca^{2+} + Mg^{2+}]} \quad \text{-- (2.4)}$$

Where, all the ionic concentrations of the elements are expressed in meq/L.

2.9. Magnesium Hazard (MH)

Magnesium is essential for plant growth; however at high content it may associate with soil aggregation and friability (Khodapanah *et al.*, 2009). More Mg^{2+} present in waters affects the soil quality converting it to alkaline and decreases crop yield (Joshi *et al.*, 2009). Szabolcs and Darab (1964) proposed MH value for irrigation water as given by the formula expressed in equation.

$$MH = \frac{[Mg^{2+}] \times 100}{[Ca^{2+} + Mg^{2+}]} \quad \text{------------------------------------} \quad (2.5)$$

Where, all the ionic concentrations of the elements are expressed in meq/L.
MH values >50 are considered harmful and unsuitable for irrigation purposes.

2.10. Aqua-Chem water quality analysis database tool

Aqua-Chem is a Water Quality database software package with functionality for graphical and numerical analysis (Abreha, 2014). Its feature has a fully customizable database Physical and Chemical parameters and provides a comprehensive selection of analytical tools such as calculations and graphs for interpreting water quality data (Hounslow, 1995; Nies *et al*., 2011).

Aqua-Chem's data analysis capabilities cover a wide range of functionalities and calculations including unit conversions, charge balances, sample comparison and mixing, statistical summaries, trend analysis, and much more.

CHAPTER THREE

3. Materials and Methods

3.1. Description of the study Area

Sheka is one of Sothern Nations Nationalities (SNNPR) zone found in South Western part of Ethiopia at a distance 675 kilo meters (kms) away from Addis Ababa. The zone is bordered on the South by Bench Maji, on the West by the Gambela Region, on the North by the Oromia Region, and on the East by Kaffa Zone. Sheka zone has Dega, Woyna-dega and kola agro ecological. But the most dominant agro ecology is Woyna-dega with an altitude ranging from of 1500 to 2300 meters above sea level (m.a.s.l). Kolla agro ecology is below 1500 m.a.s.l and the Dega has an altitude above 2300 meter. The highest elevation of study area is 2700 m.a.s.l while minimum altitude is 900 m.a.s.l. The mean annual rain fall of the study area is 2200 mm. The mean minimum temperature is in between 10 ^{0}C and 15 ^{0}C and the mean maximum temperature is in between 25 ^{0}C and 34 ^{0}C.The study was conducted in thirteen different Kebeles of three Woredas (Masha, Anderach and Yeki Woredas) and two administrative towns (Masha and Teppi towns).

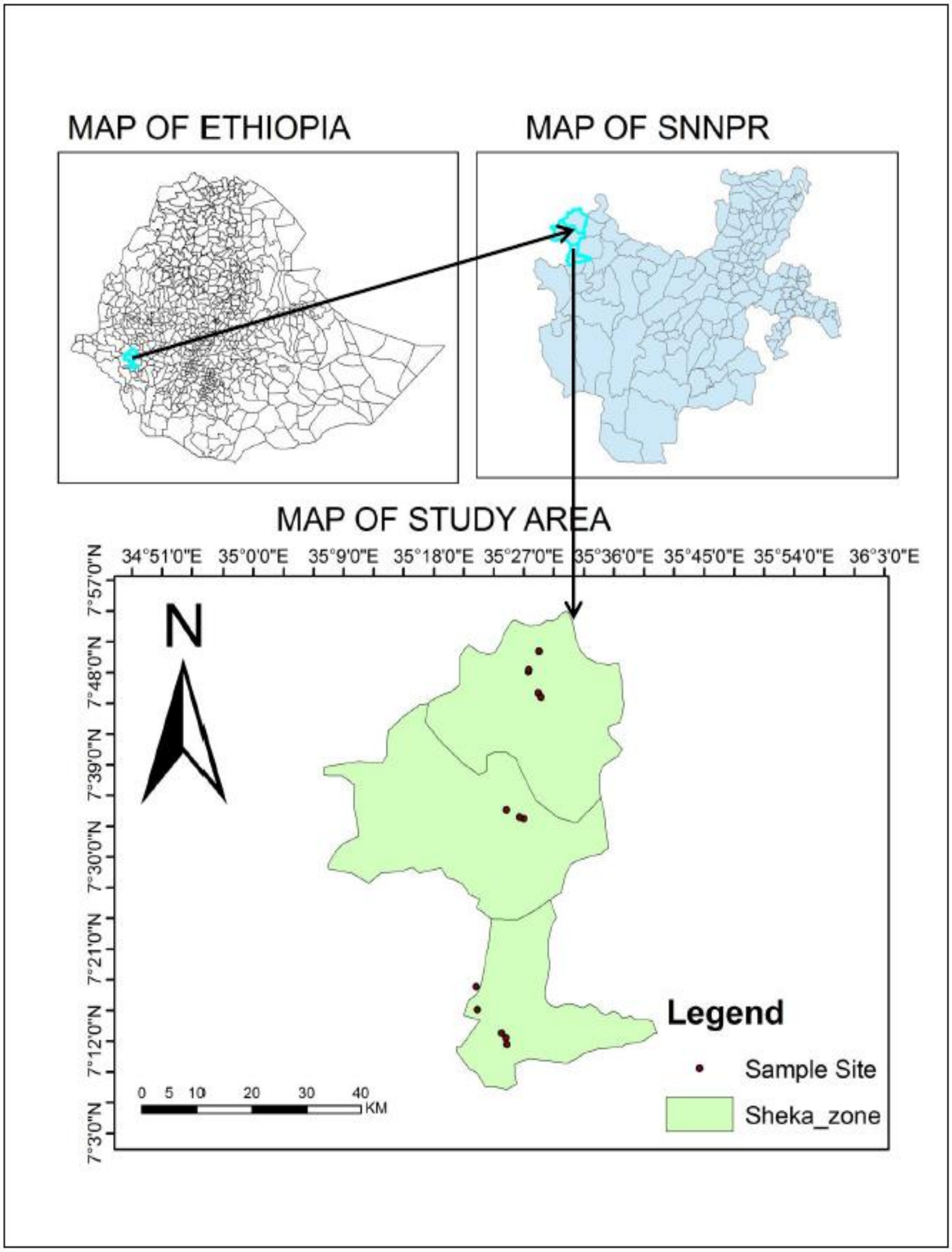

Figure 3.1 Map of study area

3.1.1. Geologic succession of study area

Ethiopia forms a part of the major structural unit of the earth's crust referred to as the "Horn of Africa". This unit comprises the Arabian Peninsula, the Red Sea, the Gulf of Aden, Djibouti, Somalia and the northern part of Kenya (Semu, 2012).

The geology of Ethiopia is strongly influenced by two major episodes.

I. The Arebo-Ethiopian swell in the Eocene to early Oligocene,
II. The major rift faulting movements throughout the African Rift system from Miocene to quaternary.

The Great Rift System of Africa bifurcates the Africa lowlands of Ethiopia with major escarpments trending north and east respectively (Semu, 2012). National Atlas of Ethiopia prepared by Ministry of Mine Energy and Water Resource department of geology in 1976 E.C classified the entire Ethiopia in to different General geological formations. According to this classification, Sheka zone (Masha, Andiracha and Yeki Woredas) the study area is under *precamberian lower complex geology* and few parts under *Cenozoic, tertiary volcanics* of *trap series* (MoWR, 1976).

Precambrian lower complex is known to be as high-grade gneisses and migmatites which is part of the Mozambique Orogenic Belt and generally consist of amphibolitesfacies (locally granulite facies) orthogneisses, parag-neisses, migmatites, and amphibolite with bands of marble. The Precambrian rocks have received attention in the current exploration activity for base and precious metals. The belts of mafic-ultramafic rocks and major shear zones bounding the two contrasting stratigraphic complexes are potential targets for gold, base metals, nickel, platinum and other mineralization (MoWR, 1976).

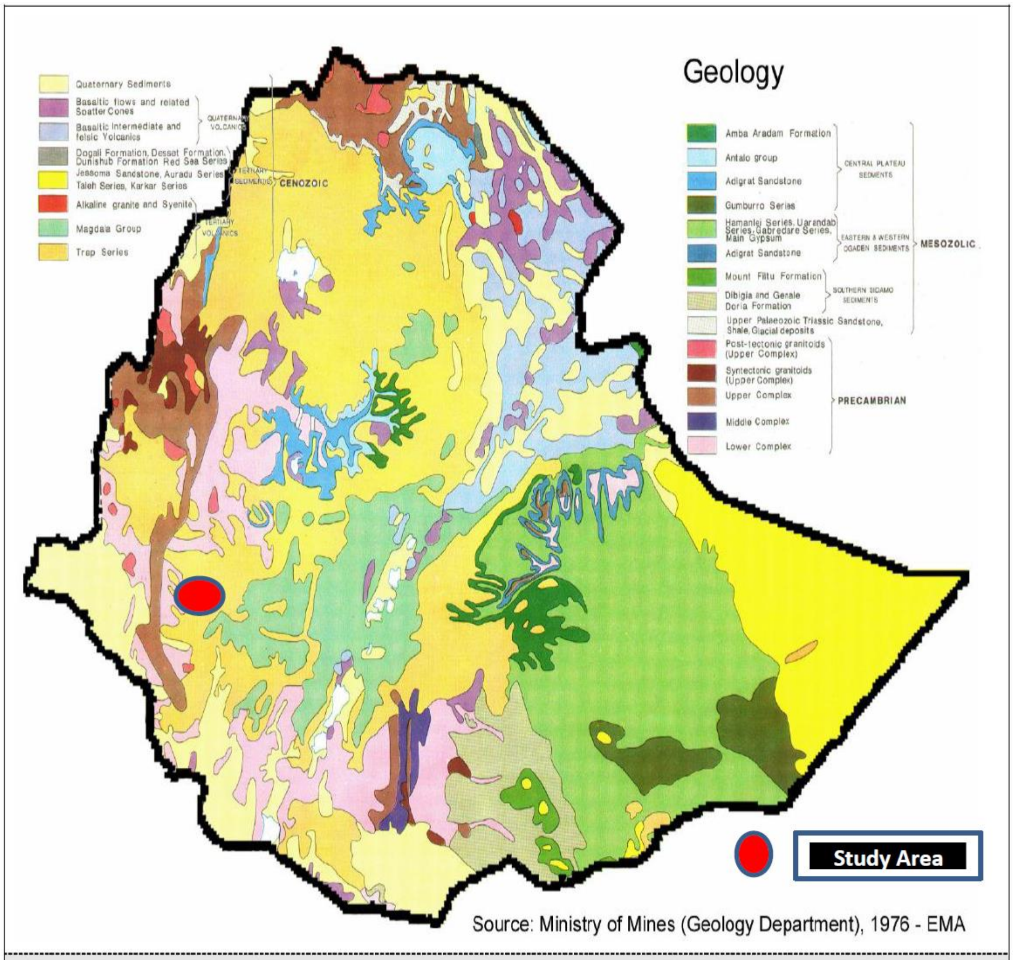

Figure 3.2: Geology of Ethiopia (Tamiru, 2006).

3.2. Study Design

Cross sectional study type was conducted in three woeda and two towns. Thirteen ground water samples were collected from seventeen constructed ground water schemes. Lottery method was employed to select water to be sampled. Thirteen water samples are taken from (Shebena, Tugiri, Echi, Ermichi, Kubito, Addis birhan, Andinet, Hibret, Toba, Shuni, Keja 1, Keja 2 and Welo) kebeles.

The research is experimental research type. This is a kind of research which provides evidences and reliable experimental results with approved values for the parameters. Experimental research takes place in the laboratory because it aims at finding out the relationship existing between two factors under controlled conditions. Thus, the experimental research strictly adopts the Scientific Method in its investigation.

Water samples were collected, stored, transported and analyzed based on WHO and UNEP standards for water sapling, storage, transportation and analysis standard procedures and protocols (WHO/UNEP, 1996).

3.3. Sample size and Sampling Procedure

3.3.1. Sample size

Thirteen water samples were collected from a total of seventeen constructed water. This is 75% of the total water points. Lottery method was adopted to select thirteen water points from the existing seventeen water points of the study area. Equal ratio classification was given to water points to be collected from woreda and towns.

3.3.2. Water sampling and analytical procedures

Thirteen ground water samples were collected from each site. Each sample were collected based on the WHO/UNEP,1996 standard protocol sampling, transportation, storage and analysis procedure. The location of each sampling points were recorded by GARMIN 72 Model Global Positioning System (GPS) instrument. Water samples were normally obtained from currently existing drilled and dug (shallow) wells fitted with hand pumps.

Each water samples were taken from ground water after manually dewatering the existed water by the hand pumps installed on the each well. The sample taken was the one after the well gets recharge.

Pre cleaned polyethylene bottles were labeled based on the sampling station codes. The sampling bottles were soaked in 1:1 HCl for 24 hours and rinsed. The bottles were again cleaned by using distilled water. At the time of sampling, the bottles were thoroughly rinsed three times by using the water which is going to be sampled. The chemical parameters like, pH and Electrical Conductivity (EC), Temperature and Total Dissolved Solids (TDS) were measured, using digital multi parameter instruments (HQ40d Model) immediately on spot just as soon as sampling was performed.

The bottles containing water samples were labeled, tightly packed, stored at 4 °C and 1:1 Nitric acid solution was added to each sample and transported to the laboratory. In the laboratory chemical analyses was performed to analyze sample of metallic substances and to determine Fe^{2+}, Mn^{2+}, Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} etc.

Table 3.1 : Sampling points, collected water source type and their GPS

Sample code	Sampling site	Type of water source	GPS Reading		
			Easting	Northing	Elevation
AWSP1	Shebena	Protected Spring	770059	836311	1920
AWHP1	Tugiri	Hand Dug borehole	769296	836579	1888
AWHP2	Echi	Hand Dug borehole	766907	837812	1918
YWHP1	Ermichi	Hand Dug borehole	761342	806049	1594
YWHP2	Kubito	Hand Dug borehole	761526	801878	1371
YWSP1	Addis birhan	Protected Spring	766007	797654	1238
TTSPP1	Andinet	Protected Spring	766813	796833	1233
TTSPP2	Hibret	Protected Spring	766987	795573	1125
MWHP1	Keja	Hand Dug borehole	770925	862722	2178
MWHP2	Keja 2	Hand Dug borehole	770960	863124	2142
MWHP3	Wello	Hand Dug borehole	772690	858925	2238
MTHP1	Toba	Hand Dug Bore hole	773261	858142	2234
MTHP2	Shuni	Hand Dug borehole	772850	866384	2252

3.4. Study Variables

3.4.1. Dependent Variables

Suitability of Sheka Zone water for drinking and irrigation purpose

3.4.2. Independent Variables

3.4.2.1. Physical parameters

Independent variables comprises of physico-chemical parameters like pH, Temperature, TDS, Turbidity and EC. Chemical cations and anions taken as independent variables consists of TA, Bicarbonates and carbonates, Calcium, Sodium , Potassium, Nitrate, Iron, Manganese, Magnesium, Chloride, Sulfate and Total Hardness (Calcium hardness and Magnesium hardness)

3.5. Sample preservation, measurement and analysis processes

3.5.1. Sample preservation

Each sample was preserved by keeping their maximum holding time until the beginning of laboratory measurement process for each parameter. The maximum holding time was kept and performed based on the WHO/UNEP, 1996 standard protocol.

3.5.2. Analysis of water sample

Institute (field level) measurement of different parameters like pH, Temperature, TDS, Turbidity and EC were held by using a digital portable multi-parameter probe (HQ40d Model). On laboratory, the chemical cations such as Calcium, Magnesium, Iron and Manganese were determined by using Atomic Absorption Spectroscopy (AAS).Chemical anions including Chloride, Carbonate and bicarbonate were estimated by volumetric titration methods. Sodium and Potassium were measured by FAAS in the laboratory of Oromia Water Works Design and Supervision Enterprise (OWWDSE). All the results were compared with standard limits recommended by (WHO, 2004).

3.5.3. Data analysis

Analysis and interpretation of all water chemistry data were carried out using Aqua-Chem 4.0 version package software and Microsoft excel package. Aqua-Chem is a fully-integrated software package developed specifically for graphical and numerical analyses and interpretation of aqueous geochemical data sets. The analyzed data is presented by using table, graphs and piper diagram.

3.6. Data quality assurance

According to (APHA, 1995) proper quality assurance procedures and precautions were taken to ensure the reliability of the results. Data quality assurances were assessed carefully and triple measurements were performed to assure quality of data. In order to minimize error, Samples were taken three times and measurement was also performed three times alone and average value was taken both for field based and laboratory based measurements. While analysis data quality was assured by triplicating data and taking the average of all results. For the sake of data quality assurance Ion Balance Error (IBE) was calculated and samples whose IBE > 5% were discarded.

$$IBE = \frac{\sum Cation - \sum Anions}{\sum Cation + \sum Anions} \times 100 \quad \text{------------------------------------} (3.1)$$

3.7. Dissemination plan

The final result of this study will be presented to Jimma Institute of Technology faculty of civil and environmental engineering, Environmental engineering chair and it will be disseminated to Sheka zone Water Mineral and Energy Department which is governmental office and other concerned organizations which might need this findings to use it. Finally it will be considered for publication in national and international reputable journals.

CHAPTER FOUR

4. Results and Discussions

4.1. Physical water quality parameters

4.1.1. pH

According to conducted measurement, pH of water varied from 5.18 to 7.85 with average value of 6.62. The highest pH reading (7.85) was observed in Masha Woreda (MWHP2) from hand pump fitted ground water. The lowest pH (5.18) was recorded in Yeki Woreda hand pump fitted hand dug borehole. According to (WHO, 2004) guide line the permissible limit of pH is from 6.5 to 8.5. Therefore; even though the upper limit pH of sampled water is not out of this range, samples with pH value bellow the standard WHO guide line value (6.5) are not suitable to drink before treatment. Water samples from hand dug bore holes of Andiracha Woreda Tugiri Kebele (AWHP1), Andiracha Woreda Echi Kebele (AWHP2), Yeki Woreda Ermich Kebele (YWHP1), spring water of Yeki Woreda Addis birhani Kebele (YWSP1) and hand dug bore hole of Masha Woreda Keja site (MWHP2) have recorded 5.92, 6.31, 5.18, 6.33 and 6.26 respectively. The lowered of pH of these water samples may be due to the acidic nature of the rock that contain elevated concentration of dissolved iron in the strata from which water originates and presence of organic acids and dissolved carbon dioxide. Adjustment of pH to neutralize acidic nature water should be performed. The ground water of study area has high concentration of Iron which may acidify the water and reduce the pH. Therefore effective aeration will reduce Iron concentration and raise the pH.

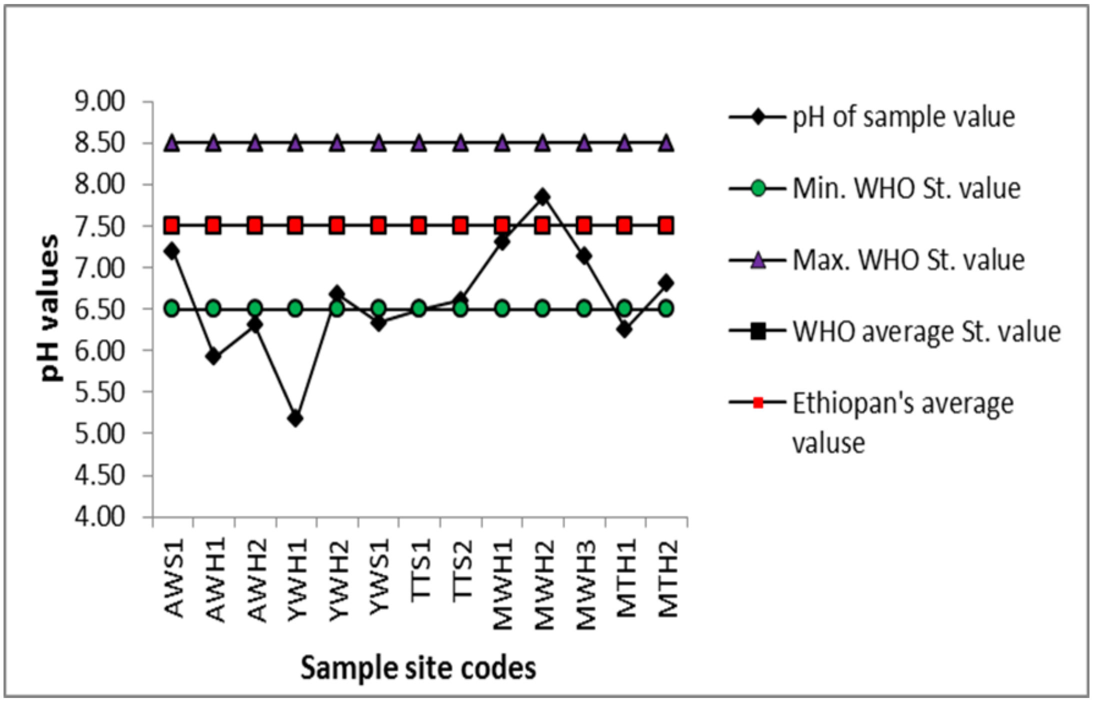

Figure 4.1 : pH values of collected ground water samples

The remaining water samples have pH value within stated guide line range of WHO and Ethiopia. Hence they are desirable and recommended for drinking. It is important to have pH of drinking water below 8 to allow disinfection with chloride process to be effective (UNICEF, 2008). Among all water samples more than half or eight samples had pH value less than 8.5 and above 6.5. Therefore, these water is suitable for effective chlorine treatment process.

4.1.2. Temperature

The temperature of collected ground water samples ranges from 19.20 ^{0}C to 28.8 ^{0}C. The average temperature of water sample is 24 ^{o}C. The least (19.20 ^{0}C) was recorded in Andiracha Woreda spring water source (AWSP1) located in Shebena Kebele while maximum temperature (28.8 ^{0}C) was recorded in Masha town hand-dug bore hole fitted with hand pump in Toba site (MTHP1). Temitope *et.,al* 2012 referring the WHO 1997 GV said that; drinking water with temperature above 25 ^{0}C is undesirable for human being and cause bone disease (pain and tenderness of bone) which children will get it more. Therefore according to the result obtained from sample water, four water sources were recorded temperature above 25 ^{0}C.Hand dug wells of Masha Woreda (MWHP1, MWHP2 and MWHP3) and hand dug well of Masha town (MTHP1) have water temperature above 25 ^{0}C with each value of 25.9 ^{0}C, 26.2 ^{0}C, 25.8 ^{0}C, 28.2^{0}C respectively. As much as possible it is preferred not to use these four water source unless the water is mixed with very cold water or kept cold until use. The remaining water sources were also exhibited high temperature which is above WHO guide line value (25 ^{0}C).

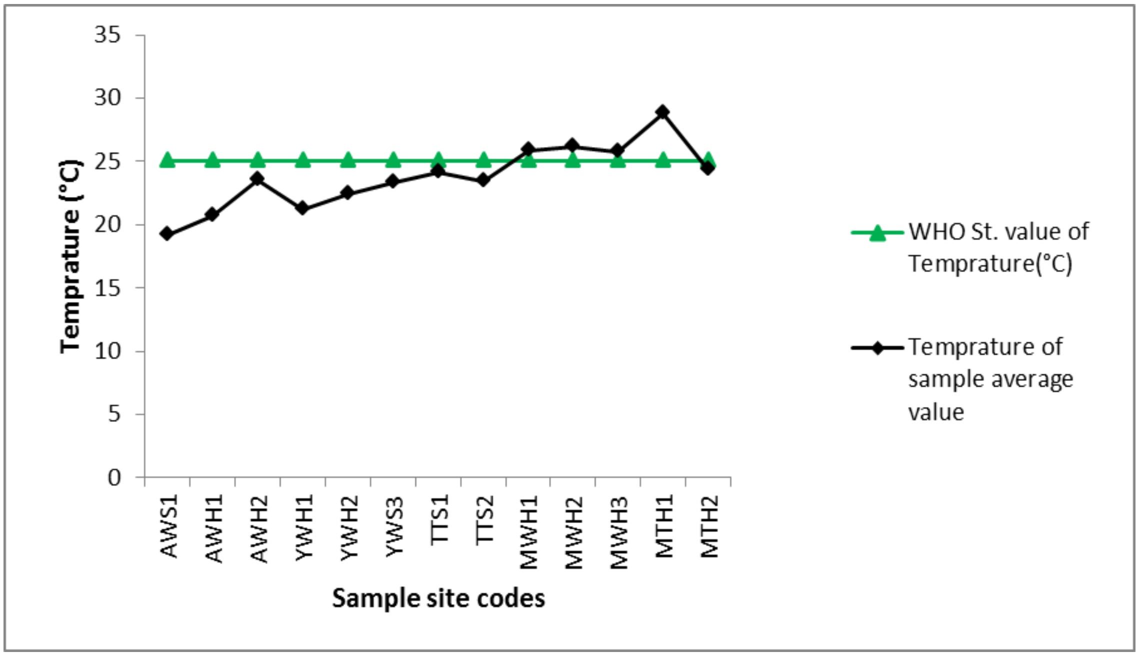

Figure 4.2: Temperature recorded values of collected ground water samples

4.1.3. Total Dissolved Solids (TDS)

In this study the minimum TDS value of water was 51.40 mg/L which was recorded from Masha town hand dug well (MTHP2) in Shuni Kebele. The maximum value was 136.20 mg/L which recorded in Yeki Woreda hand dug well (YWHP1) located in Ermichi Kebele. The mean TDS value was 95.94 mg/L. It is recommended by WHO in 2004 not to use drinking water with TDS value above 500 mg/L and Ethiopian drinking water guide line value also prohibits to not to use water with TDS value above 1500 mg/L for drinking purpose. Water with TDS value above 1000 mg/L will cause stomach discomfort (Temitope *et al.*, 2012). But all of water samples with in permitted guide line values both by WHO and Ethiopian standards (Figure 4.3).

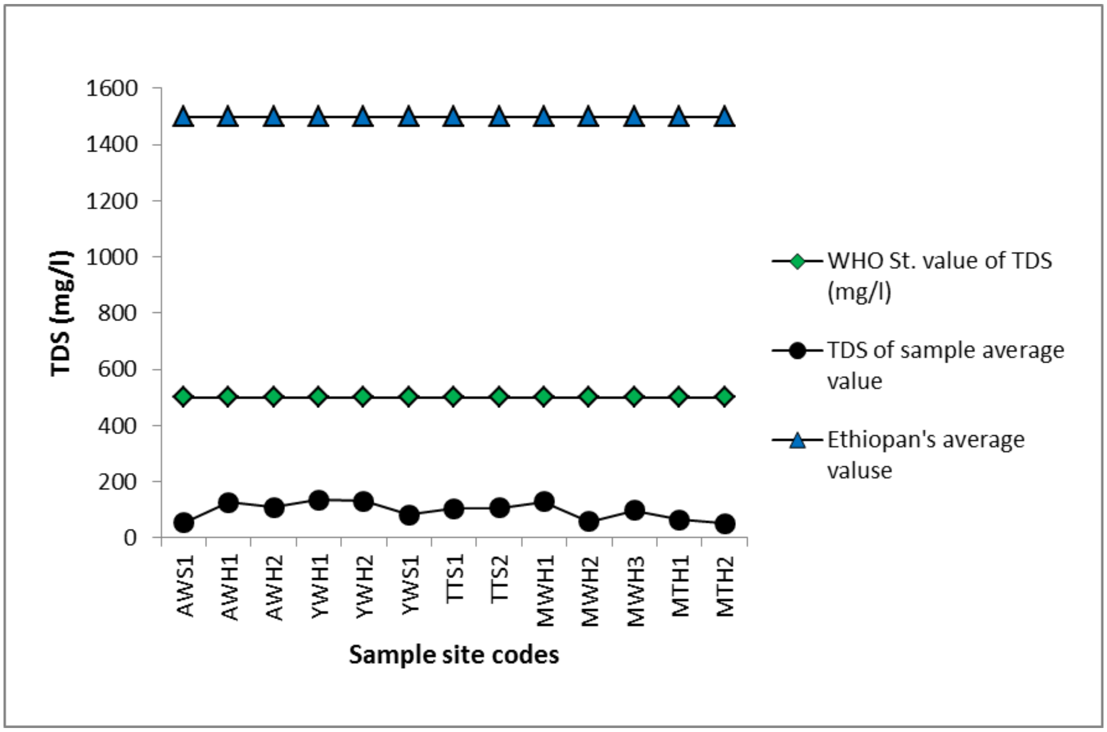

Figure 4.3 : TDS values of collected ground water samples

4.1.4. Turbidity

Most consumers can detect colors above 15 true color units, though more colored waters may be acceptable according to local preference (UNICEF, 2008). The guide line of WHO, 2004 and Ethiopian drinking water standard indicate water with turbidity value greater than 5 NTU is not recommended. According to the result obtained from the study, the lowest turbidity value is 0.12 NTU which was recorded in Yeki Woreda hand dug well (YWHP1) in Ermichi Kebele. The maximum turbidity was recorded in Yeki Woreda spring water (YWSP1) located in Addis birhan Kebele with value of 2.8 NTU. The mean turbidity value of sampled water was 0.66 NTU.

Dissolved organic matter such as humic and fulvic acids is the main component of color and highly colored waters may indicate a high potential for formation of byproducts following disinfection. Turbidity or cloudiness is also caused by suspended particles in water (UNICEF, 2008).

All sampled water had turbidity value under maximum permitted level (Figure 4.4) and it is recommended to use these water sources for drinking with criteria of turbidity standard.

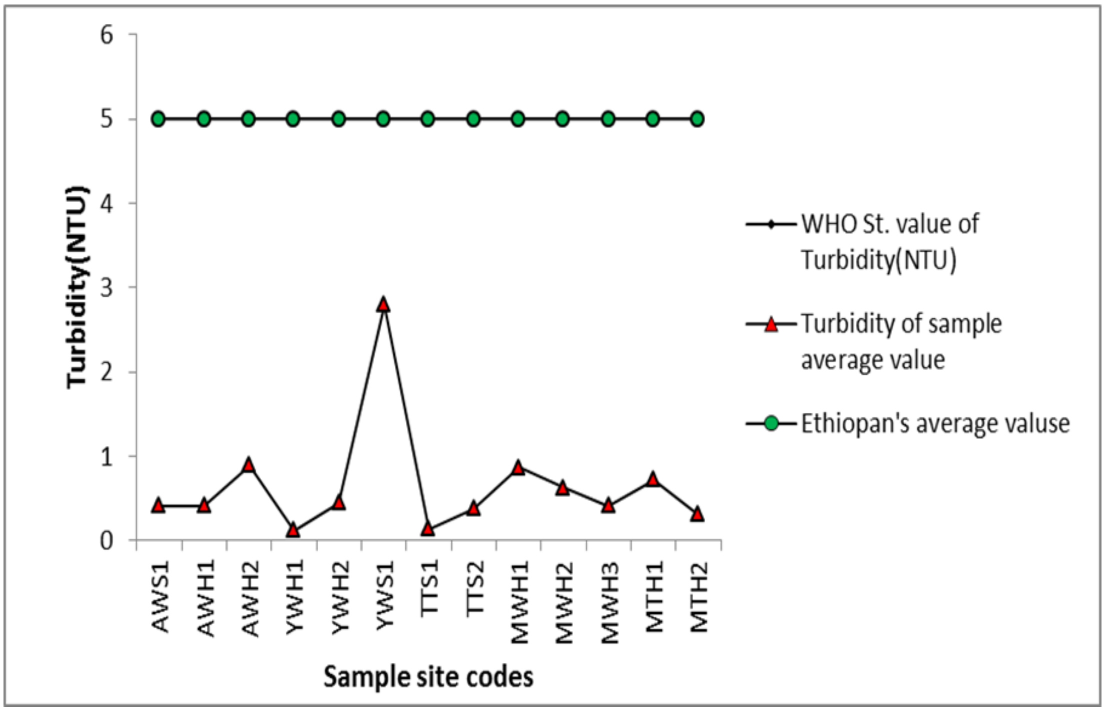

Figure 4.4 : Turbidity values of collected ground water samples

4.1.5. Electrical Conductivity(EC)

Dissolved ions increase the EC of water, which is easily measured with a meter, so EC is often used as a surrogate for TDS. The lowest conductivity value recorded was 94.20 µS/cm. This value was recorded in Masha town hand dug well (MTHP2) of Shuni Kebele. But maximum conductivity value recorded was 247.90 µS/cm which is in Yeki Woreda, Ermichi Kebele hand dug well (YWHP1). The maximum value recorded did not exceed the permissible WHO guide line value (250 µS/cm). The mean value recorded was 174.43 µS/cm as it is indicated on (Figure 4.5). The lowered EC value is preferable for health of consuming community because elevated value of conductivity above 250µS/cm can cause Anemia, liver, kidney or spleen damage, changes in blood (WHO, 1997).

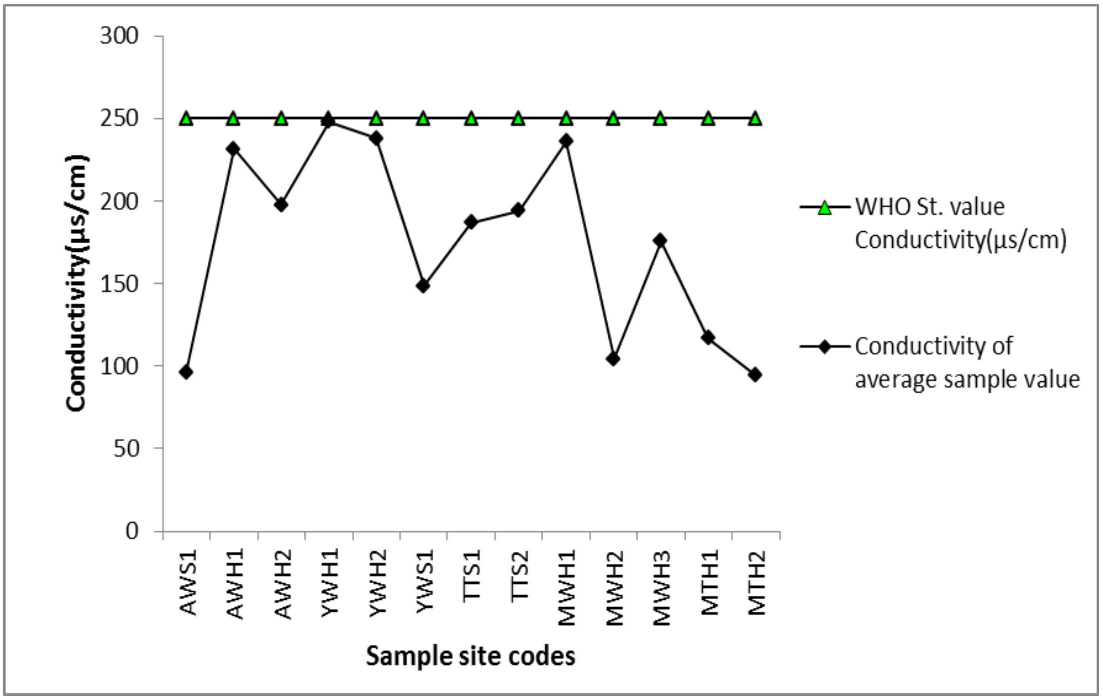

Figure 4.5 : Electrical Conductivity values of collected ground water samples

4.2. Chemical water quality parameters

4.2.1. Iron (Fe)

Dissolved metals may contribute to color in drinking water, and can stain laundry and Plumbing fixtures. Metal precipitates may also form coatings on pipe walls that can slough off as fine particulates, contributing to turbidity. Iron above 0.3 and 0.1 mg/L can cause staining, and may impact color and turbidity at lower levels (UNICEF, 2008).

In study area among water sample taken from different sites, the lowest value with iron concentration was, 0.03mg/L in Yeki Woreda hand dug well (YWHP2) located in Kubito kebele. Maximum iron concentration value (1.72 mg/L) was recorded in Masha Wereda hand dug well (MWHP2) located in Keja Kebele. About six ground water samples (Figure 8) showed iron concentration above WHO permissible limit (0.3 mg/L).Water samples in which their iron concentrations which elevated above permissible value are AWH2, TTS2, MWH2, MWH3, MTH1 and MTH2 with values of 0.92 mg/L, 0.82 mg/L, 1.72 mg/L, 0.55 mg/L, 0.4 mg/L and 0.74 mg/L respectively. The cause of high iron concentration in ground water of Sheka zone may be due to natural occurrence or abundance of Iron in the rock. Dissolution of this rock will results Iron to dissolve in water. High concentrations of iron in groundwater supplies Ethiopia were recorded in different regions of the country (FMoWR, 2000; 2001). Ground water in Chelelektu and Yirgachefe towns of Gedio zone, Sidama, Bench Maji, Kaffa and Sheka zones of SNNPR has elevated Iron concentration (FMoWR, 2000; 2001 and WHO and UNICEF, 2010). Drinking water with concentration above 0.3mg/L will cause rusting forms cancer in human body (WHO, 1997).Therefore it is important not to use water of the study area with iron concentration above permitted limit. There should be effective aeration system to oxidize high concentration of Iron from the water sources.

The reason for elevated concentration of Iron in the ground water of the study area will be due to the existence of Iron rich rocks in the place. Sedimentary rocks, Precamberian rocks, Paleozoic rocks, Mesozoic rocks, Magnetite and Hematite rocks are typically iron rich rocks (Wikipedia of geochemistry, 2017). The report prepared WHO and UNICEF in 2010 confirms the study area as one component of regions which have high iron content in their ground water. National Atlas of Ethiopia prepared by Ministry of Mine Energy and Water Resource department of geology in 1976 E.C classified the study area under *precamberian complex geology* and few parts under *Cenozoic,teritoryvolcanics of trap series.*

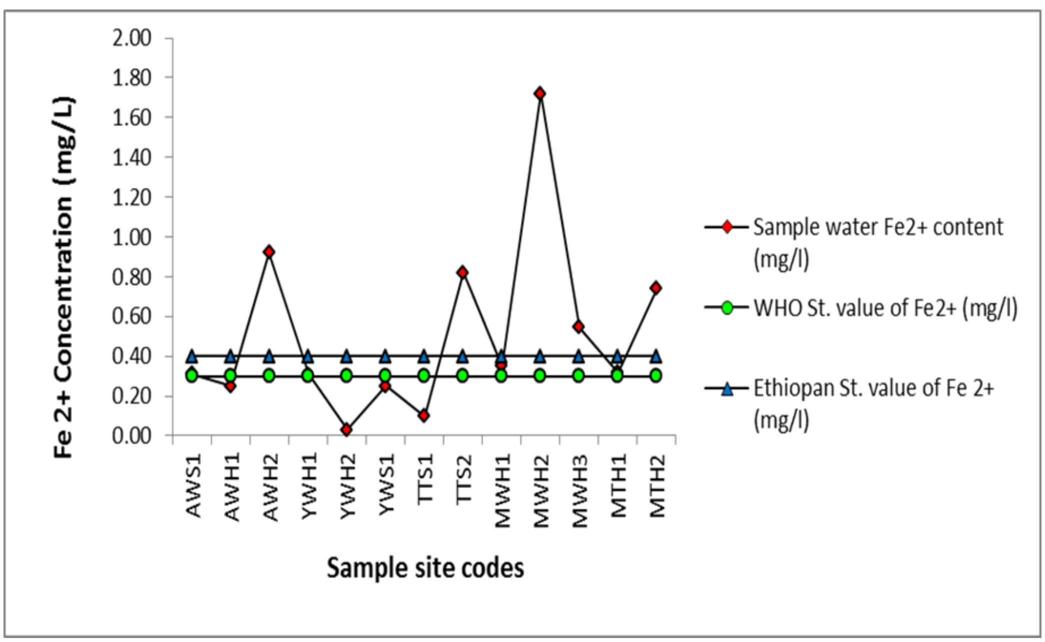

Figure 4.6 : Iron (Fe) concentration values of collected ground water samples

4.2.2. Manganese (Mn^{2+})

Anaerobic groundwater can contain much higher levels of Manganese, even above 1 mg/L. Dissolved manganese is often associated with iron, which is also soluble under anaerobic conditions. Manganese above 0.1 mg/L can cause staining, and may impact color and turbidity at lower levels (UNICEF, 2008). Concentrations below 0.05–0.1 mg/L are usually acceptable to consumers from a taste perspective but may sometimes still give rise to the deposition of black deposits in pipe. High levels of manganese in water can also have neurological effects (Wasserman *et al.*, 2006).

It was observed that the minimum concentration of Manganese in the study area was 0.01 mg/L and the maximum concentration was recorded in Masha town, Toba sample site. The average concentration of Manganese in sampled ground water was 0.51 mg/L. Four drinking water sources had Mangasese concentration above the permissible value WHO guideline value. Andiracha Woreda's spring water sample found in Shebena Kebele, Yeki Woreda hand dug well found in Ermichi Kebele, Masha Woreda hand dug well located in Welo Kebele and Masha town hand dug well located in Toba sample site exhibited high concentration of Manganese over permitted value (1.07 mg/L, 0.82 mg/L, 1.14 mg/L and 1.92 mg/) respectively.

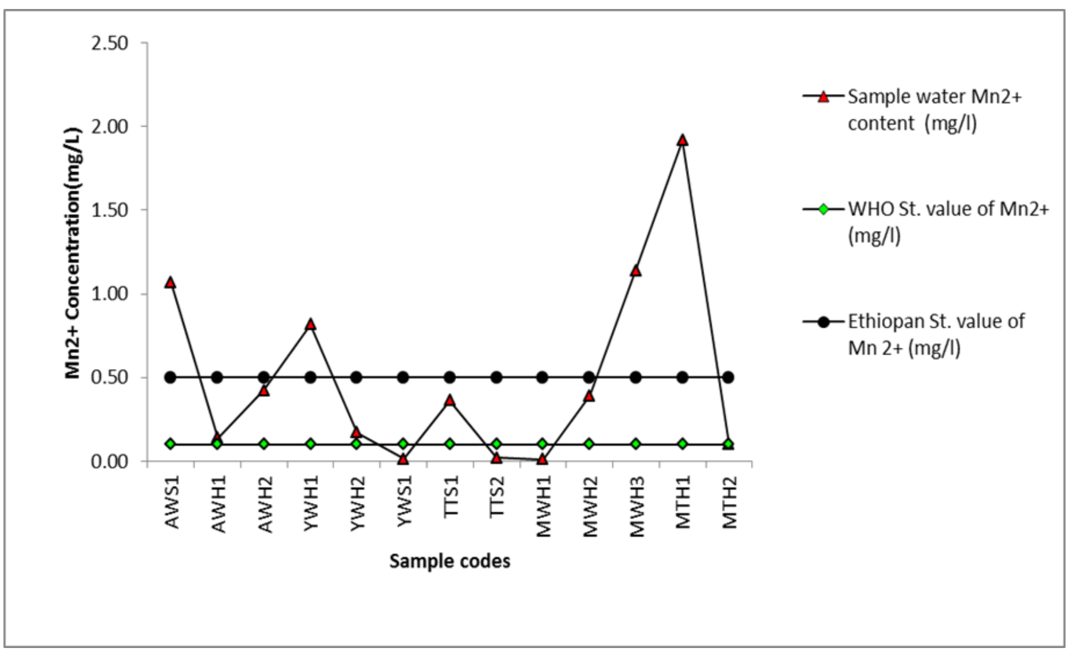

Figure 4.7 : Manganese ion (Mn) concentration values of collected ground water samples

The raised concentration may be due to dissolution of the rock in to water. Dissolved Manganese is soluble under anaerobic conditions (UNICEF, 2008).Therefore water sources with high Manganese concentrations should be supplied enough oxygen to remove manganese. Common sedimentary rocks, carbonate rocks particularly dolomite have high concentration of Manganese (Wikipedia of geochemistry, 2017).

4.2.3. Calcium (Ca)

The minimum calcium concentration in sampled water was 1.1mg/L which was recorded in spring water of Teppi town (TTSP1). Maximum concentration of calcium ion was 41.20mg/L which was recorded in hand dug well of Welo Kebele in Masha Woreda (MWHP 3). The average concentration was 15.68 mg/L.

The threshold value permitted for the calcium ion concentration in water is within the range of 100–300 mg/L (UNICEF, 2008). According to this value, all water samples had the calcium concentration below the stated threshold value and fine for utility. Drinking water with calcium concentration above 200 mg/L will cause indigestibility of fat in the body (WHO, 1997). But, all water samples in study area had calcium concentration below 200mg/L and are safe for drinking.

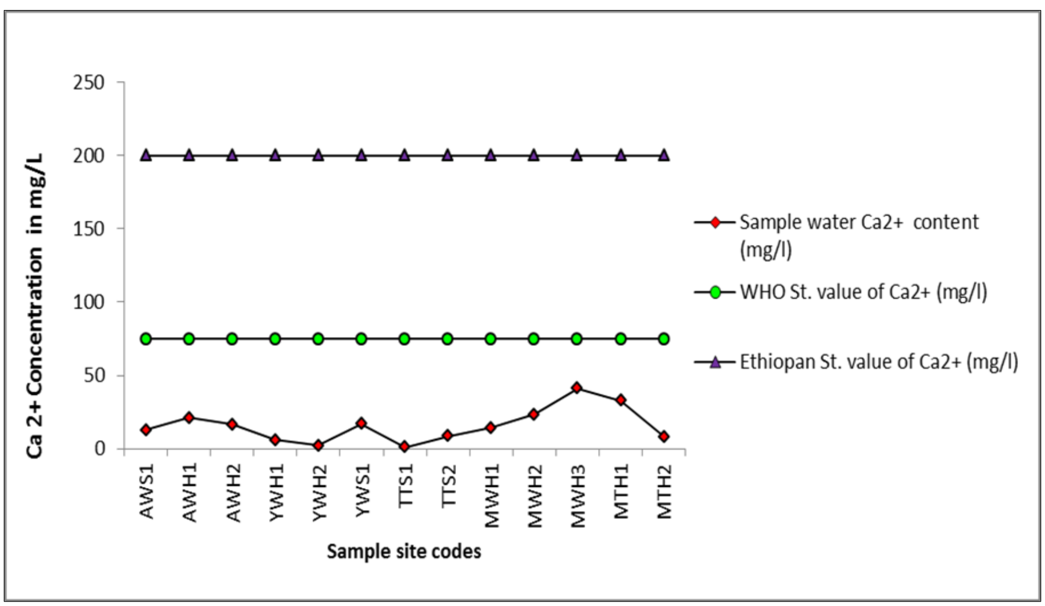

Figure 4.8 : Calcium ion (Ca) concentration values of collected ground water samples

4.2.4. Sodium (Na^+)

Although concentrations of sodium in potable water are typically less than 20 mg/L, they can greatly exceed this in some countries. It should be noted that some water softeners could add significantly to the sodium content of drinking water (WHO, 2011). In the study area the minimum sodium content of water was recorded in Yeki Woreda, Kubito Kebele with 2.14 mg/L. Maximum sodium concentration was recorded in Yeki Woreda water source with concentration of 5.94 mg/L. The average sodium concentration of sampled water was 3.47 mg/L. Even though sodium has no health concern problems at a level found in drinking water (WHO, 2004) all water sample schemes are below the range of WHO standard (200 mg/L). By considering sodium concentration of water, the water is so fine to use.

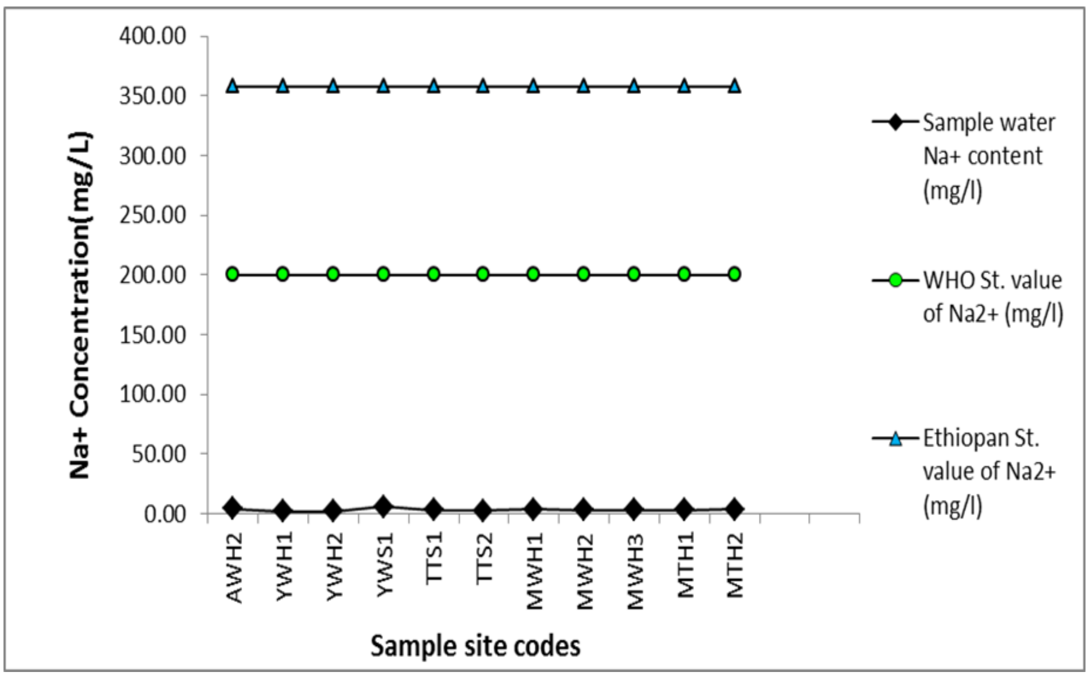

Figure 4.9 : Sodium (Na) ion concentration values of collected ground water samples

4.2.5. Potassium (K^+)

Although technologies are available to remove potassium, they are generally more expensive and redundant when combined with the softening treatment (WHO, 2009). Potassium occurs in drinking-water at concentrations well below those of health concern (WHO, 2004). WHO standard permit 10 mg/L of potassium in drinking water.

In collected water sample for this study, the minimum potassium concentration was recorded in Yeki Woreda hand dug well located in Ermichi Kebele (YWHP1) with value of 0.12 mg/L while maximum concentration was recorded in Yeki Woreda spring located in Addis birhan Kebele (YWSP1) 2.80 mg/L. Average concentration of potassium in study area is 0.66 mg/L. According to WHO guide line it is observed that all water samples have under maximum permitted limit value of potassium concentration. Hence all water sources can be used to drinking with potassium concentration criteria.

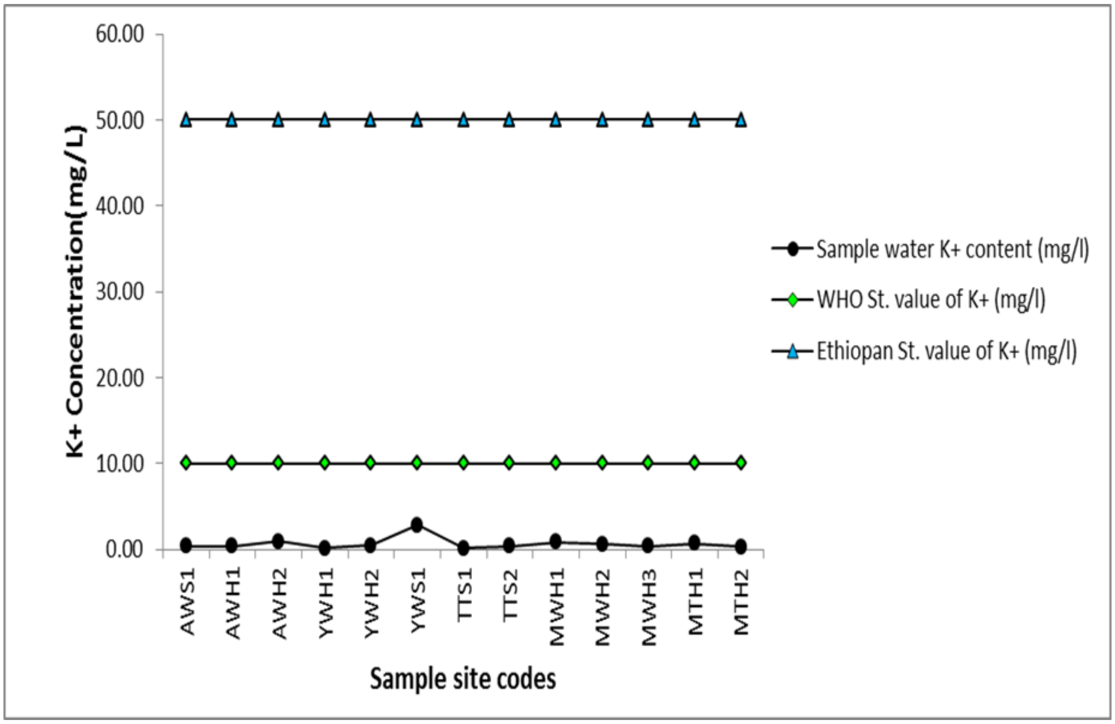

Figure 4.10 : Potassium (K) ion concentration values of collected ground water samples

4.2.6. Chloride (Cl^-)

Chloride in drinking-water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion. The main source of human exposure to chloride is the addition of salt to food, and the intake from this source is usually greatly in excess of that from drinking-water. The standards concentration of chloride should not exceed 250 mg/L (WHO, 2004).

In study area the minimum chloride concentration in water is 0.14 mg/L which was recorded in Andiracha Woredas' hand dug well (AWHP1) of Tugiri Kebele.

The maximum concentration of chloride was recorded in Masha Woreda hand dug well (MWHP2) located in Keja Kebele with value of 3.61mg/L while the mean chloride concentration value is 2.19 mg/L. According to WHO guide line value all water samples had low chloride concentration. Therefore the water is permitted for drinking.

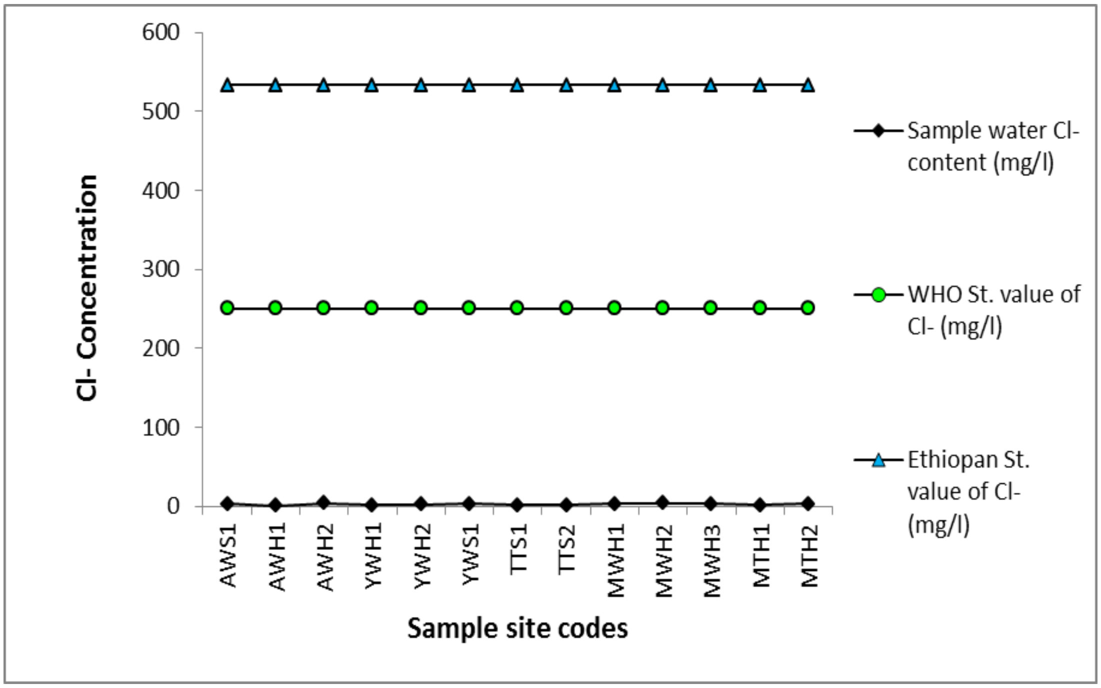

Figure 4.11 : Chloride (Cl) ion concentration values of collected ground water samples

4.2.7. Total Alkalinity

Alkalinity values of sample water taken from the study area ranges from 17 mg/L to 49 mg/L. With the mean value of 34.67 mg /L. Minimum, alkalinity (17 mg/L) is recorded in Teppi town spring water source (TTSP2) which is found in Hibret district. The maximum value (49 mg/L) was recorded in Masha Woreda hand dug well water source (MWHP3) located in Welo Kebele. WHO, 2004 Guide line states that alkalinity of drinking water should not exceed 20 mg/L of $CaCO_3$. All sampled water had total alkalinity value below recommended WHO guide line value (200 mg/L). Since the all sample values are below recommended value, they are safe for drinking.

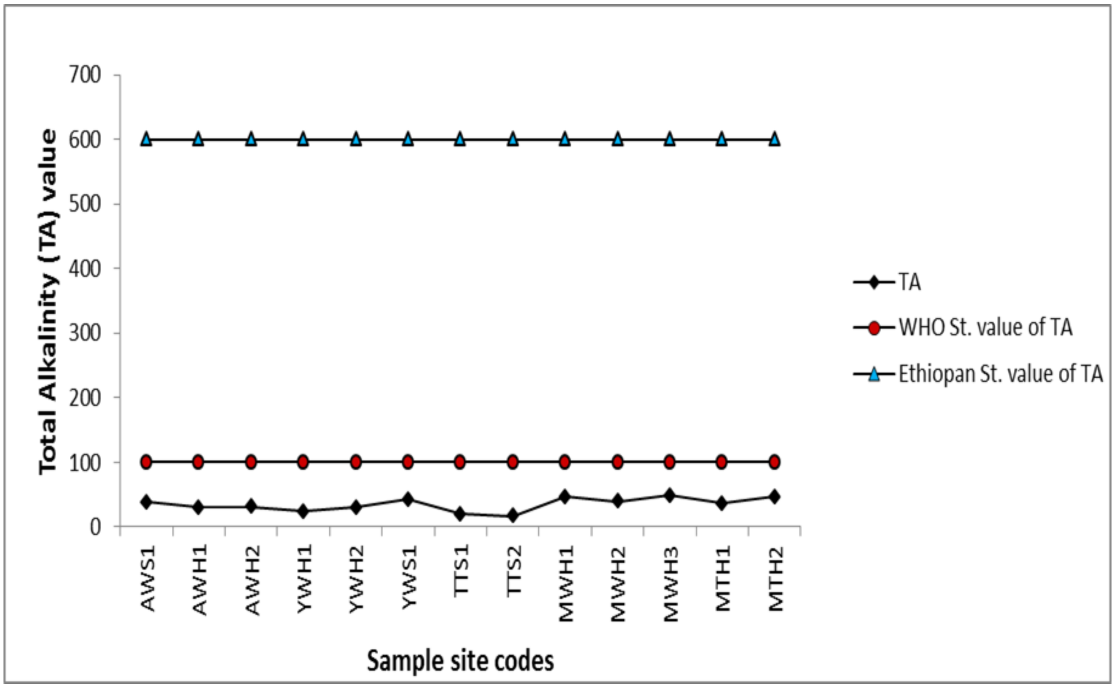

Figure 4.12 : Total alkalinity (TA) concentration values of collected ground water samples

4.2.8. Bicarbonate (HCO_3^-)

The bicarbonate content of ground water samples ranges from 14.20 mg/L to 54.30mg/L. The mean bicarbonate concentration of sample water is 31.52 mg/L. The case for the elevated TDS value in ground water is the existence of bicarbonates and other inorganic salts (principally Calcium, Magnesium, Potassium, Sodium, Chlorides and Sulfates) and small amounts of organic matter that are dissolved in water. Even though no clear cut standard guide line value for this; it is beloved to not to have more than 500 mg/L of bicarbonate in drinking water. Contentious and long term weathering of rocks will result in dissolution of rock minerals and results in formation of bicarbonate. It is showed that the tested water samples have bicarbonate concentration less than stated recommendable value and hence the tested water is still suitable for drinking.

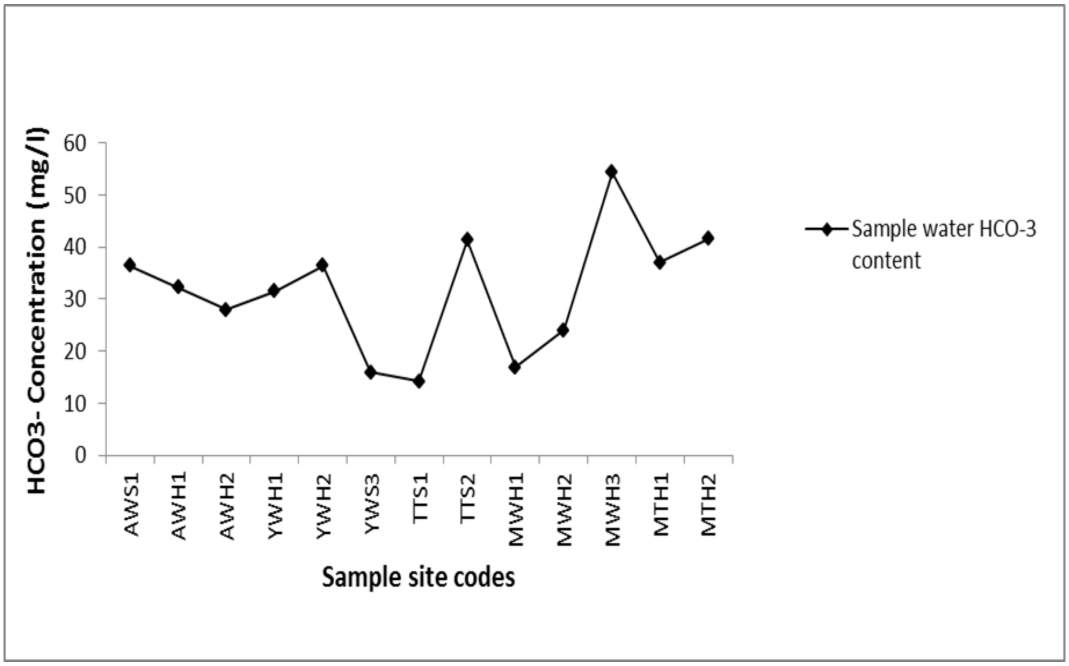

Figure 4.13 : Bicarbonate (HCO_3) concentration values of collected ground water samples

4.2.9. Nitrate (NO_3^-)

Chemicals are used in agriculture on crops and in animal husbandry. Nitrate may be present as a consequence of tillage when there is no growth to take up nitrate released from decomposing plants, from the application of excess inorganic or organic fertilizer and in slurry from animal production (WHO, 2004). The presence of nitrate and nitrite in water has been associated with methaemoglobinaemia, especially in bottle-fed infants or blue baby syndrome (WHO, 2006).

World Health Organization recommended no more than 10 mg/L of nitrate in our drinking water. According to this study the minimum nitrate concentration is 0.41 mg/L recorded in Masha town hand dug well (MTHP2) located in Shuni site which is outside from farm land and rural area and the maximum nitrate concentration is recorded in Masha Woreda hand dug well (MWHP1) with value of 11.40 mg/L. This site is in rural area in which potato farming practices with application of fertilizers from year to year takes over it. The average nitrate concentration in study area is 1.99 mg/L.

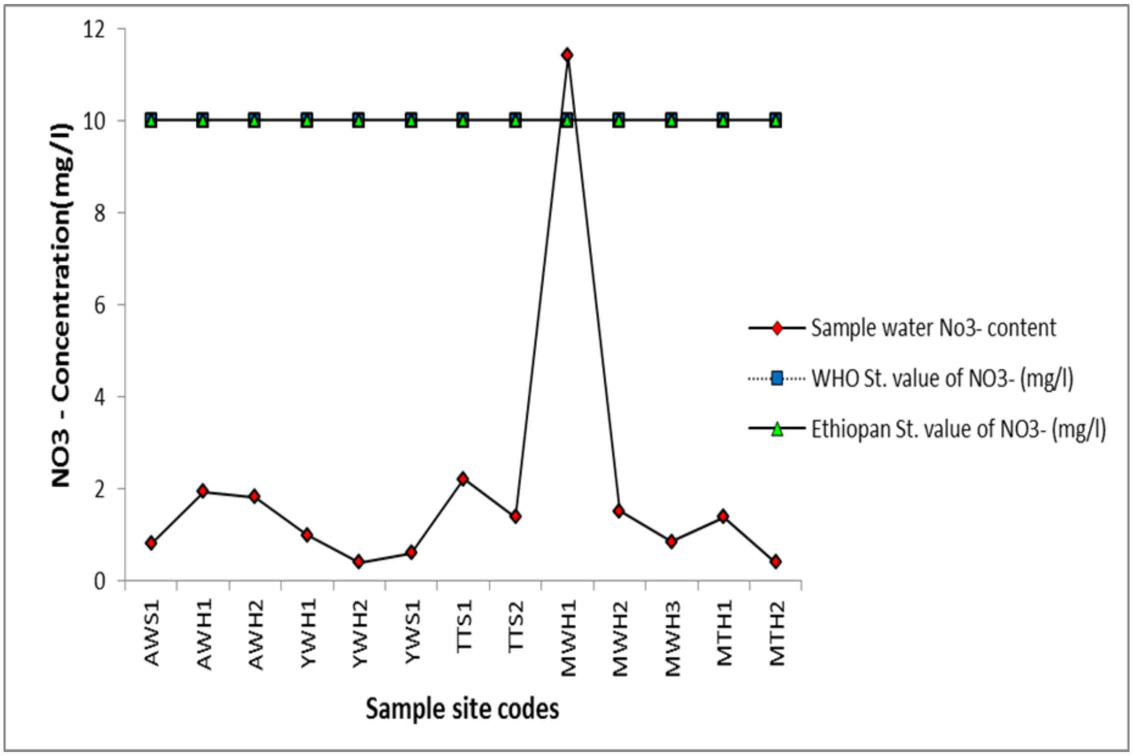

Figure 4.14 : Nitrate (NO_3^-) concentration values of collected ground water samples

4.2.10.Magnesium (Mg^{2+})

To lesser extent not exceeding the amount of calcium; presence of Magnesium ion in drinking water will result in hardness of water. It is usually expressed as the equivalent quantity of calcium carbonate. Drinking-water can be a contributor to calcium and magnesium intake and could be important for those who are marginal for calcium and magnesium. Although there is evidence from epidemiological studies for a protective effect of magnesium or hardness on cardiovascular mortality, the evidence is being debated and does not prove causality. Further studies are being conducted (WHO, 2004). According to WHO standards the permissible range of magnesium in water should be 50 mg/L. Drinking water with magnesium concentration above stated limit will results in gastro intestinal, liver or kidney damage (WHO, 1997). The result obtained from water samples shows that the minimum concentration is 1.01 mg/L recorded in Yeki Woreda hand dug well in Kubito Kebele (YWHP2), maximum value is 3.41 mg/L recorded in hand dug well water sample taken from Masha Woreda, Welo Kebele (MWHP3). Mean value of Magnesium ion measured among all samples is 1.93 mg/L. Still the measured values are not exceeding the stated guide line and hence the all water is recommended for drinking (Figure 4.15).

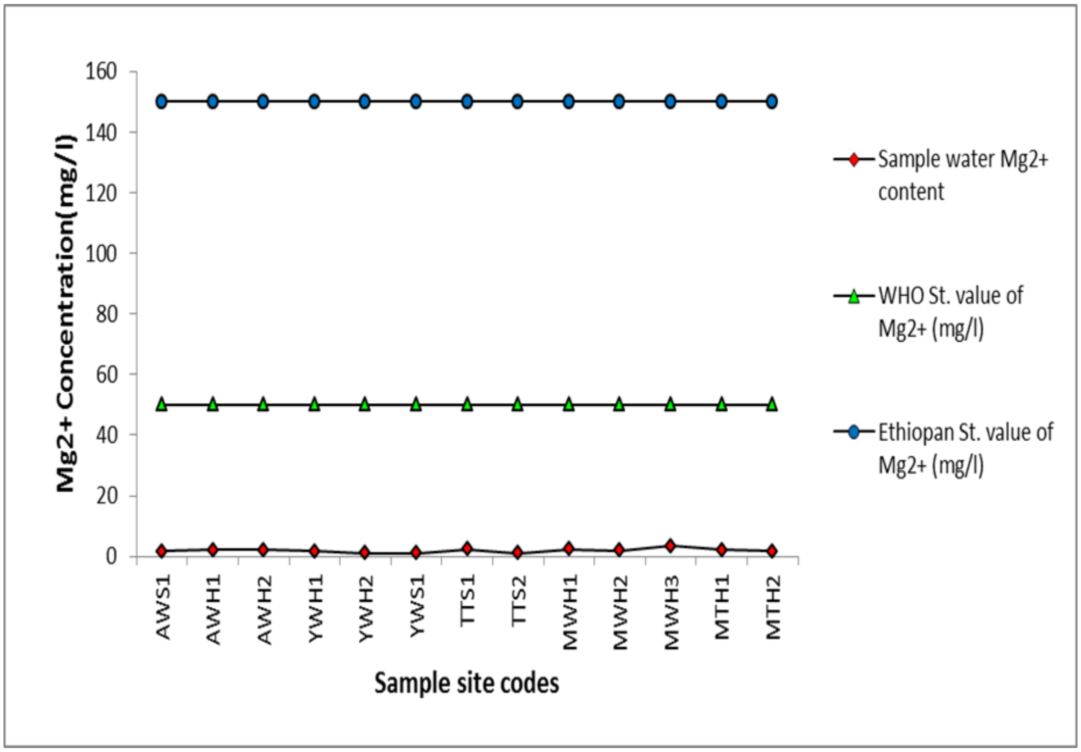

Figure 4.15 : Magnesium (Mg) concentration values of collected ground water samples

4.2.11.Sulfate (SO_4^{2-})

The presence of sulfate in drinking-water can cause noticeable taste, and very high levels might cause a laxative effect in unaccustomed consumers (WHO, 2004). Sulfate in drinking water can cause a noticeable taste above concentrations of about 250 mg/L. In the absence of oxygen and free chlorine, bacteria can convert sulfate to hydrogen sulfide, which causes a distinctive “rotten-egg” odor at concentrations as low as 0.05 mg/L. There are no health-based guide line value for sulfate or sulfide (UNICEF,2008).It is investigated that the minimum sulfate concentration in water sample was 8.24 mg/L recorded in water sample of Teppi town spring water (TTSPP2) and maximum value (41.30 mg/L) was recorded in Masha Woreda hand dug well (MWHPP3) found in Welo Kebele. The mean concentration of sulfate in sample water is 20.93 mg/L. All values of sulfate for sample water are below WHO standard guide line and it is permitted to use these water sources for drinking (Figure 4.16).

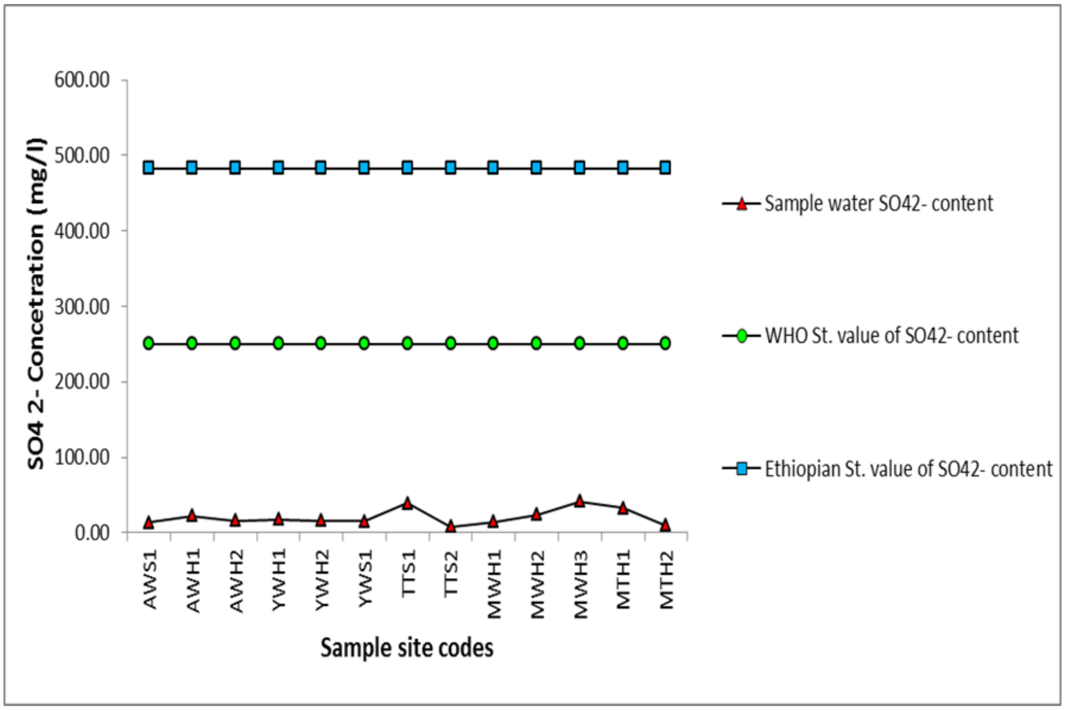

Figure 4.16 : Sulfate (SO_4^{2-}) concentration values of collected ground water samples

4.2.12.Total Hardness

Hardness is the sum of polyvalent metallic ions in water. Calcium and magnesium are the principal components, and hard waters are most common in groundwater, especially when derived from limestone, dolomite or chalk aquifer (UNICEF, 2008). Hardness in water is usually expressed as the equivalent quantity of calcium carbonate. Depending on pH and alkalinity, hardness above about 200 mg/L can result in scale deposition, particularly on heating. Soft waters with a hardness of less than about 100 mg/L have a low buffering capacity and may be more corrosive to water pipes (WHO, 2004).

No health-based guideline value is proposed for hardness. But water with the maximum hardness above 500 will result in increase in blood pressure of consumers (WHO, 1997). Some evidence suggests that hardness in drinking water may be protective with respect to cardiovascular disease, but the data are inadequate to prove a causal association (UNICEF, 2008). Hardness is expressed in terms of milligrams of calcium carbonate equivalents per liter.

The taste threshold for the calcium ion is in the range of 100–300 mg/L and the taste threshold for magnesium is probably lower. In some instances, consumers tolerate water hardness in excess of 500 mg/L. Soft water may also have a salty taste. The WHO standard guide line for hardiness is 200 mg/L $CaCO_3$.

In the study area the minimum hardness value (18.00 mg/L $CaCO_3$) is observed in Teppi town spring water and maximum value (75mg/L $CaCO_3$) was observed in Masha (MWHP3). Average total hardness value is 37.23 mg/L $CaCO_3$.

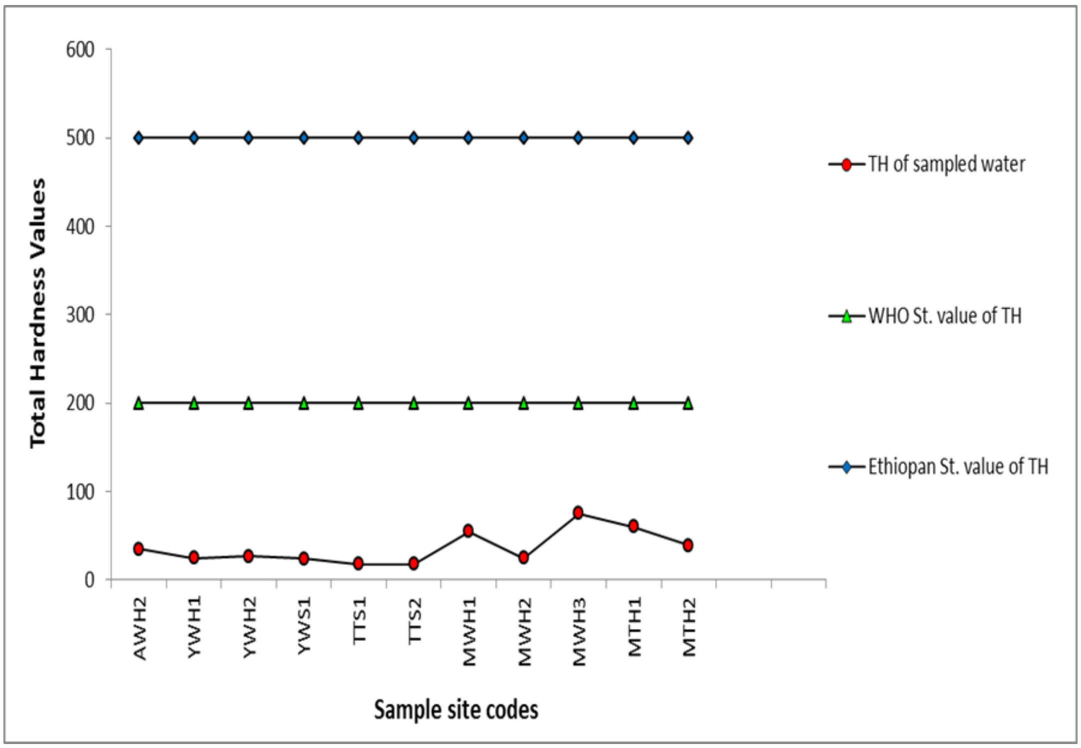

Figure 4.17 : Total Hardness (TH) concentration values of collected ground water samples

4.3. Hydro-geochemistry faces of water in study area

Naturally existing water can be represented as solution of three major cationic constituents, Ca^{2+}, Mg^{2+} and alkaline metals and of three anionic constituents, SO_4^{2-}, Cl^- and those contributing to alkalinity, i.e., CO_3^{2-} and HCO_3^-. Therefore, linear plots are most suitable for the representation of groundwater composition (Piper, 1994). The concentrations of major cations (Ca, Mg, Na) and anions (HCO_3^-, SO_4^{2-}, Cl^-) of the groundwater are plotted in a Piper diagram (Piper 1944) to verify the water type (Figure 4.18). The groundwater of the study area (different sample sites of drinking water in Sheka zone) is dominated by alkaline earth metals (Ca, HCO_3 and SO_4). Hydrogen bicarbonate and sulfate dominates in soil of groundwater formation in almost all sites but few sample sites with other geochemical constituents. Ca-HCO_3-SO_4 is found in six sample of groundwater (AWSP1, AWHP1, MWHP2, MWHP3, TTSP2 and YWHP2). The major contributing geochemical component in water of study area is Ca-HCO_3-SO_4 (Table 4.1). Therefore, water type of Sheka Zone is dominantly described as Ca-HCO_3-SO_4. Similarities and differences among groundwater samples can be revealed from the trilinear diagram first presented by (Piper, 1944) because water of similar qualities will tend to plot together as groups. The trilinear diagram has a three distinct fields- two triangular shapes and one diamond shape. The geochemical contents of each ground water samples can be plotted on piper diagram and their regime and possible rock sources from which water has been obtained the geochemical can easily be described.

Table 4.1 : Water type of study area

Sample No.	Sampling locaion	Water Type
AWSPP1	Shebena	Ca-HCO_3-SO_4
AWHPP1	Tugri	Ca-HCO_3-SO_4
AWHPP2	Echi	Ca-Na-HCO_3-SO_4
YWHPP1	Ermich	Ca-SO_4-HCO_3
YWHPP2	Kubito	Ca-HCO_3-SO_4
YWSPP1	Addis brihan	Ca-SO_4-HCO_3
TTSPP1	Andinet	Ca-SO_4-HCO_3
TTSPP2	Hibret	Ca-HCO_3-SO_4
MWHPP1	Keja	Mg-SO_4-HCO_3
MWHPP2	keja 2	Ca-HCO_3-SO_4
MWHPP3	Welo	Ca-HCO_3-SO_4
MTHPP1	Toba	HCO_3-SO_4
MTHPP2	Shuni	Ca-Na-SO_4-HCO_3

According to the result obtained from analysis, the alkaline earth metal (Ca) ion is dominating 11 water sources. Only two water sources are occupied with other cation one with Mg and the other without dominating cation. Calcium is the principal component, and hard water is most common in groundwater, especially when derived from limestone, dolomite or chalk aquifers (UNICEF, 2008). From the finding of analysis it is possible to conclude that almost all water sources of sample site in Sheka zone, especially those of eleven water sources the water providing strata is lime stone or dolomite. It is also observed that there is heterogeneity in hydro geochemical patterns (cation and ion concentrations) among different sources. These heterogeneity is due to variations in the sources of elements and changes in the solubility factor of calcite ($CaCO_3$), Dolomite ($CaMg(CO_3)2$), Sidenite ($FeCO_3$) and others. The above idea was supported and elaborated by (Tesema *et al.*, 2012).

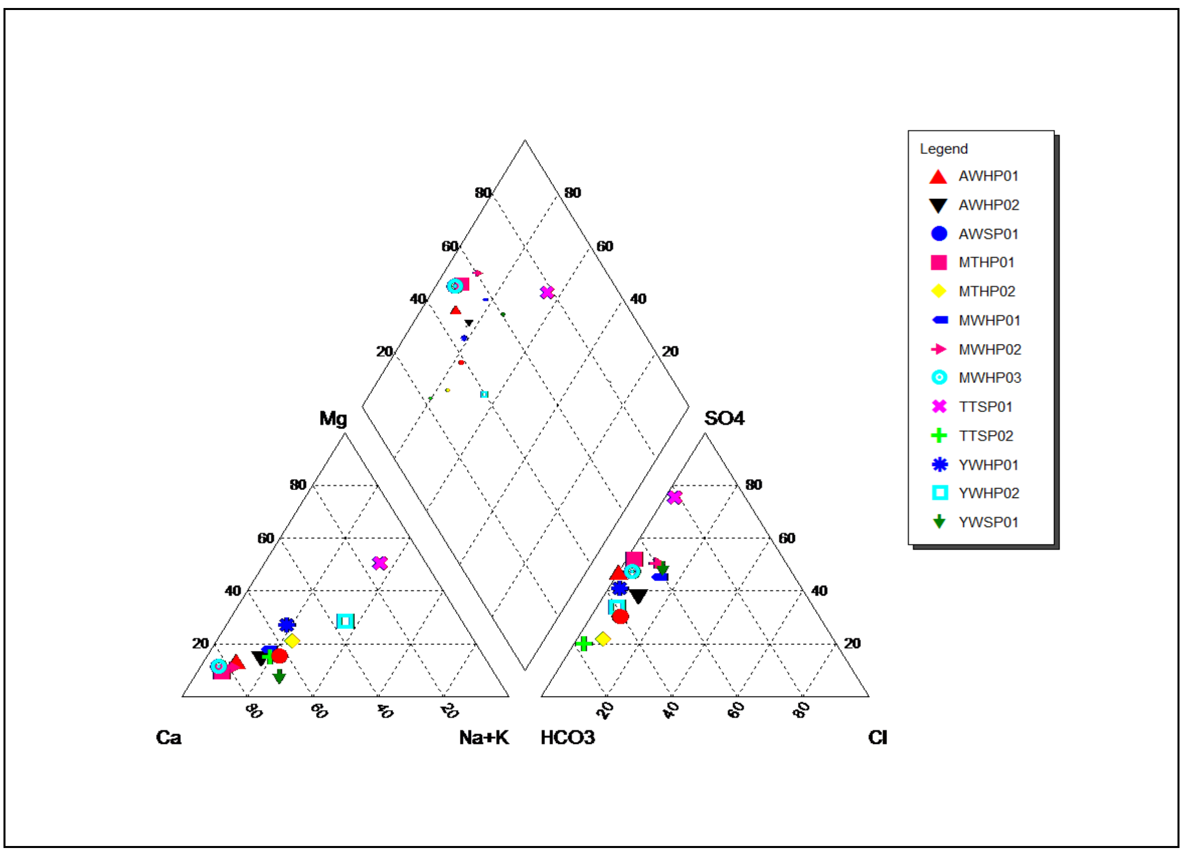

Figure 4.18 : Piper diagram showing water type of study area

4.4. Evaluation of water quality for irrigation use

4.4.1. Electrical Conductivity

In study area the value of ground water electrical conductivity ranges from 94.20µs/cm to 247.90µs/cm. The average electrical conductivity is 174.43µs/cm (Table 4.3).The maximum electrical conductivity value was recorded in Yeki Woreda hand pump which is located in Ermich Keble while the minimum value was observed in Masha Woreda hand pump found in Keja Kebele. The most desirable limit of EC in irrigation water use is prescribed as 250µS/cm (WHO, 2004). Based on the WHO guide line value of water quality standard for irrigation water use, the water samples collected from the study area are safe at all.

4.4.2. Sodium Adsorption Ratio

The SAR value of groundwater samples ranges from 0.65 to 2.36 with a mean value of 1.37 (Table 4.5). The highest SAR (2.36) was observed at location TTSP1 (Teppi town spring water source) and the lowest SAR (0.65) was observed at MWHP3 (Masha Woreda hand dug well water source). SAR was estimated based on the given formula expressed in above equation for the each sample location of the study area. The suitability of the water samples were evaluated by determining the SAR value and these were categorized into different irrigation classes based on salinity and alkalinity hazards. Water samples with SAR value fewer than 10 is taken as suitable water source for irrigation purpose. Therefore, according to the standard, all water samples are suitable for irrigation purpose.

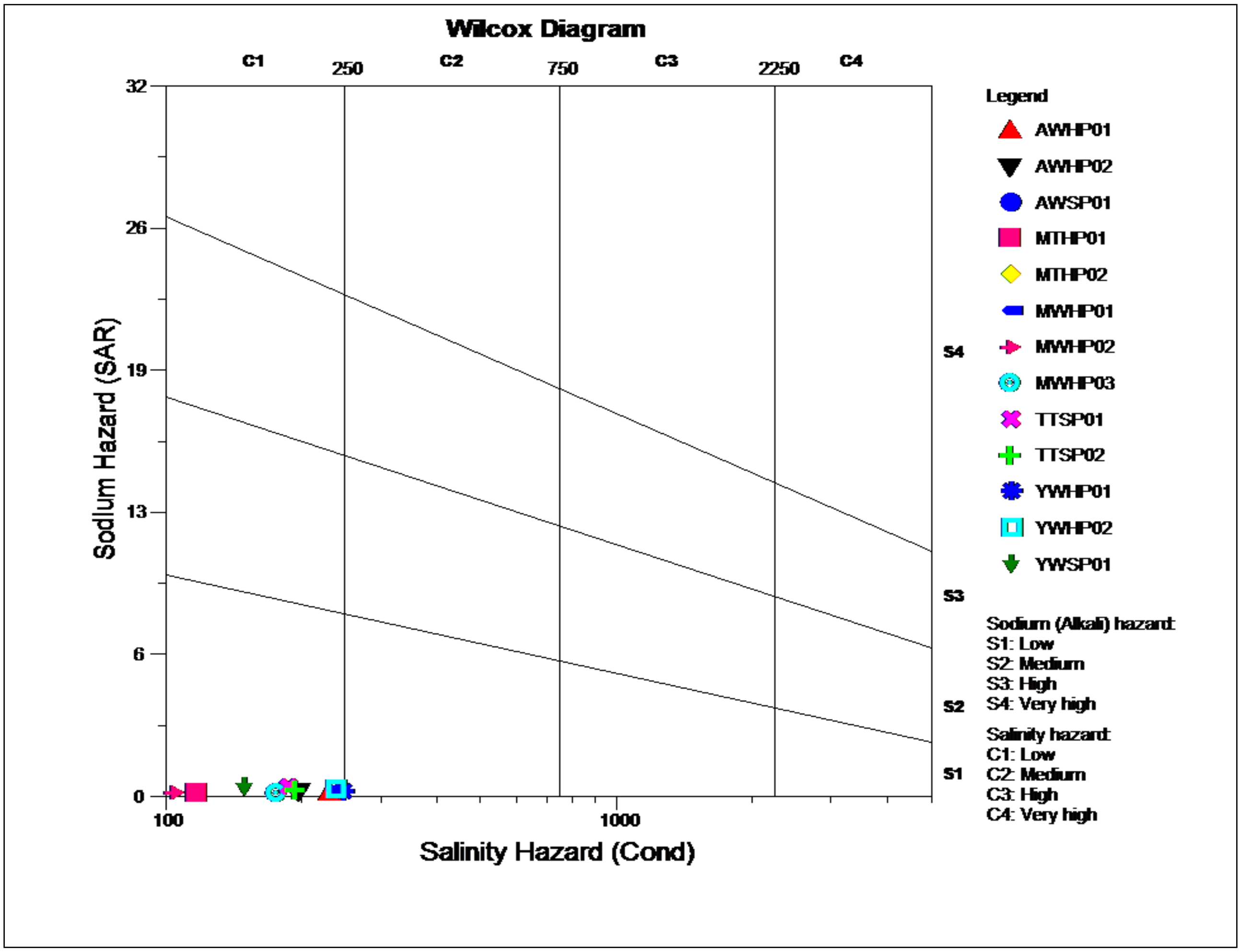

Figure 4.19 : Wilcox diagram showing SAR value of water of the study area

4.4.3. Soluble Sodium Percentage

The SSP value of groundwater samples ranges from 11.99 to72.23 with a mean value of 36.14 (Table 4.5). The highest SSP was observed at location YWHP2 located in Kubito Kebele and the lowest SSP was observed at MWHP3 in Welo Kebele .SSP was estimated based on the given formula expressed on above equation for each samples. When concentration of Na^+ is high in irrigation water, Na^+ tends to be absorbed by clay particles, displacing Mg^{2+} and Ca^{2+} ions.

Excess SSP, combining with carbonate, leads to formation of alkali soils, whereas with chloride, saline soils are formed. Neither soil will support plant growth (Rao, 2006). Irrigation with Na-rich water results in ion exchange reactions: uptake of Na^+ and release of Ca^{2+} and Mg^{2+} (Khodapanah *et al*., 2009). This causes soil aggregates to disperse, reducing its permeability (Tijani, 1994). Classifying groundwater based on SSP following Wilcox (1955) it was found that groundwater samples have SSP values <60 (AWSP1, AWHP1, AWHP2, YWHP1, YWSP1, TTSP2, MWHP1, MWHP2, MWHP3, MTHP1 and MTHP3) are safe for irrigation water use based on SSP criteria. But YWHP2 and TTSP1 are water which is not considered as safe for irrigation indicating permissible irrigation water type limit (Table 4.5).

4.4.4. Residual Sodium Carbonate

According to the result obtained with this study the maximum RSC value was 33.27 and the minimum RSC value was -2.23 with mean RSC of 13.92.RSC value with <1.25 was considered safe for irrigation (Table:- 10) and it is considered unsuitable if it is greater than 2.5. The high RSC value in water leads to precipitation of Ca^{2+} and Mg^{2+} (Raghunath, 1987). As a result, the relative proportion of sodium in the water is increased in the form of sodium bicarbonate (Sadashivaiah *et al*., 2008). The higher concentration of RSC causes the soil structure to deteriorate, the movement of air and water through the soil is restricted; soil alkalinity increases and plant growth is shunted (Reddy, 2011). AWSP1, AWHP1, AWHP2, YWHP1, TTSP1, YWHP2, TTSP2, MTHP1, MWHP3 and MTHP2 were unsuitable for irrigation water use while YWSP3, MWHP1 and MWHP2 are suitable for irrigation use. Most the groundwater samples (3 samples) fall to suitability class (RSC< 1.25).

Negative RSC(YWSP3 and MWHP2) indicates that Na^+ buildup is unlikely since sufficient Ca^{2+} and Mg^{2+} are in excess of what can be precipitated as CO_3^{2-}.Based on Residual sodium carbonate (RSC) values, all the samples of study area having values less than 1.25 showed on Table 4.5 were safe for irrigation with RSC value creameries.

4.4.5. Magnesium Hazard

Magnesium plays major role for plant growth; however it will cause soil aggregation and friability at high level (Khodapanah *et al*., 2009). More Mg^{2+} present in waters affects the soil quality converting it to alkaline and decreases crop yield (Joshi *et al*., 2009).

It is stated that MR value < 50% is suitable for irrigation and > 50% is not suitable (Khodapanah *et al*., 2009). In the study area MR value ranges from 6.06% to 68.27%

(Table 4.6). Except one ground water sample (TTSP1) which is spring water of Teppi town having 68.27% MR value all of 12 ground water are suitable for irrigation water having MR value <50% (Table 4.5).

4.4.6. Kelly's Ratio

Sodium measured against Ca^{2+} and Mg^{2+} is used to calculate Kelly' Ratio (KR). Kelly's Ratio of more than 1.0 indicates an excess level of sodium in waters. Hence, waters with a Kelley's Ratio less than one are suitable for irrigation, while those with a ratio more than one are unsuitable for irrigation. According to the result from measurement, all groundwater samples fall in good (suitable) for irrigation (Table 4.5).

Table 4.2 : Ranges of chemical parameter values recorded in study area

Parameters	Range	Average	WHO Standards	Ethiopian Standards
Ca^{2+}	1.12 - 41.20	15.68	75	200
Mg^{2+}	1.01 - 3.1 4	1.93	50	150
Na^{+}	2.14 - 5.94	3.47	200	358
K^{+}	0.40 - 8.60	4.15	10	50
Mn^{2+}	0.00 - 1.9	0.5	0.1	0.5
Fe^{2+}	0.03 - 1.72	0.51	0.3	0.4

Table 4.3 : Physico-Chemical parameter values recorded in Study area

Site	Sample Location	Temprature (^{0}C)	EC (µS/cm)	pH	Turbidity (NTU)	TDS (mg/L)
AWSP1	Shebena	19.2	96.13	7.2	0.41	53.02
AWHP1	Tugri	20.7	231.4	5.92	0.41	126.3
AWHP2	Echi	23.5	197.8	6.31	0.89	107.9
YWHP1	Ermich	21.2	247.9	5.18	0.12	136.2
YWHP2	Kubito	22.4	238.1	6.68	0.45	131.5
YWSP1	Addis brihan	23.3	148.7	6.33	2.80	81.4
TTSP1	Andinet	24.1	186.9	6.5	0.14	103.6
TTSP2	Hibret	23.4	194	6.6	0.38	107.23
MWHP1	Keja	25.9	236	7.31	0.87	129.4
MWHP2	keja 2	26.2	104.3	7.85	0.63	57.7
MWHP3	Welo	25.8	175.4	7.13	0.41	97.3
MTHP1	Toba	28.8	116.8	6.26	0.72	64.3
MTHP2	Shuni	24.3	94.2	6.8	0.31	51.4
Minimum		19.20	94.20	5.18	0.12	51.40
Maximum		28.80	247.90	7.85	2.80	136.20
Mean		23.75	174.43	6.62	0.66	95.94
WHO (2004)		≤ 15	250	6.5-8.5	5	500
Ethiopian Standards		NA	NA	6.5-8.5	5	1,500

NA: Not Available

Table 4.4 : Chemical anion values recorded in Study area

Site	TH	TA	HCO_3^-	CO_3^{2-}	Cl^-	SO_4^{2-}	NO_3-
AWSP1	38.0	38.4	36.4	0.00	3.14	14.08	0.82
AWHP1	45.0	29.7	32.3	0.00	0.14	22.4	1.95
AWHP2	35.0	31.0	28	0.00	3.41	16.4	1.82
YWHP1	25.0	24.0	31.5	0.00	1.12	18.09	1
YWHP2	27.0	30.0	36.4	0.00	2.14	16	0.41
YWSP1	24.0	42.0	15.9	0.00	2.96	15.4	0.61
TTSP1	18.0	20.0	14.2	0.00	1.19	39	2.23
TTSP2	18.0	17.0	41.3	0.00	0.98	8.24	1.39
MWHP1	55.0	47.0	16.9	0.00	3.13	14.4	11.4
MWHP2	25.0	39.2	24	0.00	3.61	24.1	1.53
MWHP3	75.0	49.0	54.3	0.00	2.81	41.3	0.86
MTHP1	60.0	36.4	37	0.00	1.16	32.8	1.4
MTHP2	39.0	47.0	41.6	0.00	2.74	9.87	0.41
Min	18.0	17.0	14.00	0.00	0.14	8.24	0.41
Max	75.0	49.0	54.30	0.00	3.61	41.30	11.40
Mean	37.2	34.67	31.52	0.00	2.19	20.93	1.99
WHO, 2004	200	100	200	NA	250	250	10
Eth. Std.	500	600	NA	NA	533	483	10

Table 4.5 : Irrigation water quality parameters

Site	SAR	SSP	RSC	KR	MH
AWSP1	1.82	39.97	21.98	0.34	12.62
AWHP1	0.89	33.46	9.15	0.13	9.24
AWHP2	1.40	20.09	9.46	0.23	11.54
YWHP1	1.13	27.76	23.98	0.29	22.87
YWHP2	1.71	72.23	33.27	0.68	32.27
YWSP1	1.97	32.02	-2.23	0.33	6.23
TTSP1	2.36	72.14	10.67	0.89	68.27
TTSP2	1.24	45.46	31.75	0.28	11.94
MWHP1	1.37	27.14	0.50	0.24	14.02
MWHP2	0.85	31.61	-1.14	0.12	7.72
MWHP3	0.65	11.99	9.69	0.07	7.64
MTHP1	0.75	13.30	2.19	0.09	6.06
MTHP2	1.66	42.63	31.64	0.37	18.27
Minimum	0.65	11.99	-2.23	0.07	6.06
Maximum	2.36	72.23	33.27	0.89	68.27
Average	1.37	36.14	13.92	0.31	17.59

Table 4.6: Metallic cations values and analyzed parameter values to show suitability of water for irrigation use

Site	**Na^+**	**K^+**	**Ca^{2+}**	**Mg^{2+}**	**CO_3^{2-}**	**HCO^{3-}**	**SAR**	**SSP**	**RSC**	**KR**	**MH**
AWSP1	4.90	4.70	12.60	1.82	0.00	36.4	1.82	39.97	21.98	0.34	12.62
AWHP1	3.04	8.60	21.01	2.14	0.00	32.3	0.89	33.46	9.15	0.13	9.24
AWHP2	4.26	0.40	16.40	2.14	0.00	28	1.40	20.09	9.46	0.23	11.54
YWHP1	2.19	0.70	5.80	1.72	0.00	31.5	1.13	27.76	23.98	0.29	22.87
YWHP2	2.14	6.00	2.12	1.01	0.00	36.4	1.71	72.23	33.27	0.68	32.27
YWSP3	5.94	2.60	17.00	1.13	0.00	15.9	1.97	32.02	-2.23	0.33	6.23
TTSP1	3.14	6.00	1.12	2.41	0.00	14.2	2.36	72.14	10.67	0.89	68.27
TTSP2	2.71	5.25	8.41	1.14	0.00	41.3	1.24	45.46	31.75	0.28	11.94
MWHP1	3.91	2.20	14.10	2.3	0.00	16.9	1.37	27.14	0.50	0.24	14.02
MWHP2	3.02	8.60	23.20	1.94	0.00	24	0.85	31.61	-1.14	0.12	7.72
MWHP3	3.08	3.00	41.20	3.41	0.00	54.3	0.65	11.99	9.69	0.07	7.64
MTHP1	3.14	2.20	32.70	2.11	0.00	37	0.75	13.30	2.19	0.09	6.06
MTHP2	3.70	3.70	8.14	1.82	0.00	41.6	1.66	42.63	31.64	0.37	18.27
Minimum	2.14	0.40	1.12	1.01	0.00	14.20	0.65	11.99	-2.23	0.07	6.06
Maximum	5.94	8.60	41.20	3.41	0.00	54.30	2.36	72.23	33.27	0.89	68.27
Average	3.47	4.15	15.68	1.93	0.00	31.52	1.37	36.14	13.92	0.31	17.59

Table 4.7 : Recorded Metallic cations values of sampled water

Parameters	Readings	Unit	AWSP1	AWHP1	AWHP2	YWHP1	YWHP2	YWSP3	TTSP1	TTSP2	MWHP1	MWHP2	MWHP3	MTHP1	MTHP2
Ca^{2+}	R 1	mg/L	12.59	21.02	16.39	5.79	2.11	16.99	1.13	8.42	14.11	23.21	41.01	32.69	8.14
	R 2	mg/L	12.61	21.01	16.4	5.81	2.12	17.01	1.11	8.41	14.11	23.22	41.03	32.71	8.13
	R 3	mg/L	12.6	21.02	16.4	5.8	2.12	17	1.12	8.39	14.12	23.22	41.03	32.71	8.14
	Mean	mg/L	12.6	21.02	16.40	5.8	2.12	17.00	1.12	8.41	14.11	23.22	41.02	32.70	8.14
Mg^{2+}	R 1	mg/L	1.83	2.15	2.14	1.73	1.02	1.12	2.42	1.15	2.3	1.95	3.41	2.12	1.83
	R 2	mg/L	1.8	2.14	2.14	1.72	1.03	1.13	2.4	1.14	2.31	1.94	3.42	2.11	1.83
	R 3	mg/L	1.83	2.12	2.14	1.7	1.01	1.13	2.41	1.14	2.3	1.94	3.41	2.11	1.81
	Mean	mg/L	1.82	2.14	2.14	1.72	1.02	1.13	2.41	1.14	2.30	1.94	3.41	2.11	1.82
Na^{+}	R 1	mg/L	4.91	3.03	4.27	2.19	2.14	5.91	3.12	2.71	3.91	3.02	3.09	3.12	3.69
	R 2	mg/L	4.91	3.04	4.26	2.18	2.14	5.96	3.16	2.7	3.89	3.01	3.07	3.15	3.69
	R 3	mg/L	4.89	3.04	4.26	2.19	2.13	5.96	3.14	2.71	3.92	3.02	3.07	3.14	3.72
	Mean	mg/L	4.90	3.04	4.26	2.19	2.14	5.94	3.14	2.71	3.91	3.02	3.08	3.14	3.70
K^{+}	R 1	mg/L	0.41	0.43	0.89	0.13	0.44	2.81	0.14	0.38	0.85	0.62	0.39	0.71	0.32
	R 2	mg/L	0.41	0.4	0.89	0.12	0.46	2.8	0.139	0.38	0.88	0.63	0.41	0.71	0.31
	R3	mg/L	0.41	0.39	0.89	0.12	0.44	2.8	0.141	0.38	0.87	0.63	0.42	0.73	0.31
	Mean	mg/L	0.41	0.41	0.89	0.12	0.45	2.80	0.14	0.38	0.87	0.63	0.41	0.72	0.31
Mn^{2+}	R 1	mg/L	1.06	0.14	0.42	0.82	0.17	0.01	0.361	0.02	0.01	0.391	1.14	1.91	0.102
	R 2	mg/L	1.07	0.14	0.43	0.81	0.17	0.01	0.36	0.02	0.01	0.392	1.14	1.921	0.1
	R 3	mg/L	1.07	0.13	0.42	0.82	0.17	0.02	0.362	0.02	0.013	0.391	1.14	1.92	0.101
	Mean	mg/L	1.07	0.14	0.42	0.82	0.17	0.01	0.36	0.02	0.01	0.39	1.14	1.92	0.10
Fe^{2+}	R 1	mg/L	0.32	0.25	0.92	0.31	0.03	0.25	0.09	0.82	0.35	1.72	0.55	0.32	0.74
	R 2	mg/L	0.31	0.25	0.92	0.31	0.03	0.25	0.10	0.82	0.35	1.72	0.55	0.32	0.74
	R 3	mg/L	0.31	0.25	0.92	0.31	0.03	0.25	0.11	0.82	0.35	1.72	0.54	0.31	0.74
	Mean	mg/L	0.31	0.25	0.92	0.31	0.03	0.25	0.10	0.82	0.35	1.72	0.55	0.32	0.74

CHAPTER FIVE

5. Concussions and Recommendations

5.1. Conclusions

The major water source for most of the communities of the study area is ground water. Physico-chemical parameters of the samples were measured on the field. Chemical anion and cations of the water samples were evaluated in laboratory. The finding sowed that, temperature of four water samples is above WHO permissible value and other parameters like EC, Turbidity, pH and TDS are below guide line value and are safe for use. In a place where potato farming practice with application of fertilizer for long years, the Nitrate (NO_3^-) concentration of one sample water showed above WHO permissible value which is > 10 mg/L. But other anionic parameters like total hardness, total alkalinity, bicarbonate, chloride and Sulfate are bellow permissible value of World Health Organization and are suitable for use. Metallic cation evaluation of sampled water relatively good to use for drinking except six water samples whose Iron concentration is above WHO permitted limit of 0.3 mg/L and eight water samples showed elevated Manganese concentration above the standard limit which is 0.1 mg/L.

To confirm whether the water is suitable for irrigation or not we evaluated different parameters and almost all water samples are good for irrigation use. (SAR, SSP and KR) of all water samples are in the range of good. Especially the best determining parameter for suitability criteria of water for irrigation use is SAR and the result indicates SAR value of all water samples are good for irrigation use. According to Magnesium Hazard criteria, only one water samples is not in the range of good irrigation water.

5.2. Recommendations

Based on the field based and laboratory based measurements with addition of analysis computed, the quality of ground water and it's suitability for drinking and irrigation is evaluated. By recognizing the quality of water and comparing with different international standard values, the following recommendations were stated.

- Aeration treatment process or other treatment alternative is needed for water who's Iron and Manganese concentration is above WHO guide line value which is 0.3 mg/L and 0.1 mg/L respectively. Sheka Zone Water Mineral and Irrigation Department and other concerned bodies responsible for the treatment options.
- Prevention of entry of Nitrate (NO_3) form any sources (e.g. from agricultural farms, grazing lands, wastes and like) should be performed.
- It is necessary to protect water points and schemes from entrance of different animals in order to prevent damage and entrance of animal waste into it.
- It is important to prepare flood prevention trenches or construction of elevated slab for head of water source to prevent entrance of flood and waste.
- Continuous monitoring of groundwater along with quality study will minimize the chances of further deterioration of water sources.
- As the result shows almost all water is suitable for irrigation use. Therefore it is better to aware the community to use the water for irrigation in order to have farming activity to improve their productivity in dry seasons.

References

Adeyemi, O. Oloyede,O. and Oladiji, A. (2006). Effect of Leachate-contaminated Groundwater on the Growth and Blood of Albino of Rats. The Internet Journal of Hematology.3(2):1-6.

Adepoju-Bello A, Ojomolade O, Ayoola GA, Coker. (2009). Quantitative analysis of some toxic metals in domestic water obtained from Lagos metropolis. The Nigerian Jouranal of Pharmacy. 42(1):57-60.

Adepoju-Bello A, Alabi. Heavy metals. (2005). A review paper. The Nigerian Jornal of Pharmacy. 37: 41-45.

American Public Health Association. (1995). Standard Methods for the Examination of Water and Waste water,14th Edition.76-265

Bonde JP, Giwercman A, Ernst E. (1996). Identifying environmental risk to male reproductive function by occupational sperm studies: logistics and design options. Occup. Environ. Med. (53):511–519.

Brindha, K. and Elango, L. (2011). Fluoride in Groundwater: Causes, Implications and itigation Measures. Applications and Environmental Management. Anna University, Chennai; 1-27.

Chilton J. (1996).Water Quality Assessments A Guide to Use of Biota, Sediments and Water in Environmental Monitoring.UNESCO/WHO/UNEP. ISBN 0 419 21590 5.

David keith T and Lary W.,Ground water Hydrology. 3rd ed. Arizona state university. John Wiely and Sons,Inc. (2005).

Eric G. Reichard, Michael Land, Steven M. Crawford, Tyler Johnson, Rhett R. Everett, Trayle V. Kulshan, Daniel J. Ponti, Keith J. Halford, Theodore A. Johnson1, Katherine S. Paybins, and Tracy Nishikawa. (2003).Geohydrology, Geochemistry, and Ground-Water Simulation-Optimization of the Central and West Coast Basins, Los Angeles County, California. U.S. Geological Survey Water-Resources Investigations Report; 1-46.

Harter T., Groundwater Quality and Pollution. University of California.FWQP Reference

Sheet; (2003):11(2).

Hounslow, A. W., (1995). Water quality data; analysis and interpretation.Unite States of America: LEWIS.

John HD. (2002). Heavy metals: a meaningless term. IUPAC Technical Report, Pure Applied Chemistry:74: 793-807.

Kalu A. Okorafor , Uwem P. Enyenihi and Somtoochukwu Ojukwu.(2015). Concentrations of some metals in sediment, Macrobrachium macrobrachion, and Tympanotonus fuscatus obtained from the Great Kwa River, Calabar, Nigeria.Biosciences Research in Today's World Open Access freely available online ISSN: 2476-7905 Biosciences Research Support Foundation:1(1):32-39.

Karthikeyan.N, Saranya.A,and Sashikkumar M.C.,(2013). Spatial analysis of Ground water quality for virudhunagar district, Tamil Nadu Using GIS.

Khodapanah, L., W.N.A. Sulaiman and N. Khodapanah,(2009). Groundwater Quality Assessment for different Purposes in Eshtehard District, Tehran, Iran. European Journal of Scientific Research, 36(4) : 543-553.

Mazor, E.,(1991). Applied Chemical and Isotopic Groundwater Hydrology. USA, Canada and Latin America: Halsted Press.

Marcovecchio JE, Botte SE, Freije RH. Heavy metals, major metals, trace elements. In: Nollet LM, ed. Handbook of Water Analysis. 2nd ed. London: CRC Press; (2007).

Meghdad Pirsaheb, Touba Khosravi, Kiomars Sharafi, Leila Babajani and Mansour Rezaei.(2013). Measurement of Heavy Metals Concentration in Drinking Water from Source to Consumption Site in Kermanshah – Iran.World Applied Science journal: 21(3):416-423.

Muhammad, M., Samira, S., Fayal, A., and Farrukh, J., (2013). Assessment of Drinking Water Quality and its impact on Residents Health in Bahawalpur City. International Jornal of Humanities and Social Science, Vol.3, No.15.

Olumuyiwa I. Ojo, Fred A.O. Otieno and George M. Ochieng.(2012).Groundwater: Characteristics, qualities, pollutions and treatments: An overview.International

Journal of Water Resources and Environmental Engineering:4(6),162-170.

Paul Pavelic, Mark Giordano, Bernard Keraita, Vidya Ramesh and Tamma Rao.(2012). Ground water Availablity and use in Sub-Saharan Africa: A review of 15 Countries. International Water Management Institute, Sri Lanka: doi: 10.5337/2012.213.p274.

Peden M, Oyebite K, Ozanne-Smith J, Hyder AA, Branche C, Rahman FA, Rivara F. (2009). Rapport mondial sur la prévention des traumatismes de l'enfant. World Health Organization; Silderberg, M.S., Higher Education Chemistry. The Molecular Nature of Matter and Change, Mc Graw Hill. p.250.

Raghunath, M., (1987). Groundwater, 2nd Ed., Wiley Eastern Ltd., New Delhi, India

Reddy, K.S.S.N. and T.A. Reddy, (2011). Qualitative characterization of groundwater resources for irrigation: a case study from Srikakulam area, Andhra pradesh, India. International Journal of Engineering Science and Technology, 3(6) 4879-4887.

Rogers D. Masters, Myron JC, Hone B. (1999). (Cited Feb. 4th 2010) . Poisoning the well; Neurotoxic metals, water treatment and human behaviour.

Sadashivaiah, C., C.R. Ramakrishnaiah and G. Ranganna, (2008). Hydrochemical Analysis and Evaluation of Groundwater Quality in Tumkur Taluk, Karnataka State, India. Int. J. Environ. Res. Public Health, 5(3): 158-164

Sajil Kumar , Jegathambal and James.(2014). Factors influencing the high fluoride concentration in groundwater of Vellore District, South India. Springer-Verlag Berlin Heidelberg: (72),2437-2446.

Saravanan, K. Srinivasamoorthy, K. Prakash,R. Gopinath, S. and Suma,C. (2015). An Evaluation of Hydrogeochemistry of Groundwater in Upper Vellar Sub Basin using Mineral Stability and Solute Transport Modelling. Elsevier:4,1119-1125.

Semu Moges. (2012). Agricultural Use of Ground Water in Ethiopia: Assessment of Potential and Analysis of Economics, Policies, Constraints and Opportunities. International Water Management Institute.

Silesh Bekele,Aster Denekew, Mekonnen Leulseged,Wullibald Loskandi,Mekonnen Ayana and Tena Alamirew.(2007). Water Resource and Irrigation Development in

Ethiopia.International Water Management Institute:working paper 123: 78.

Subba Rao., Surya Rao ,Venktram Reddy.G, Nagamani.M, Vidyasagar.G and Satyanarayana. (2011). Chemical characteristics of groundwater and assessment of groundwater quality in Varaha River Basin,Visakhapatnam District, Andhra Pradesh, India.Springer Science + Business Media B.V:184:5189–5214.

Tamiru Alemayehu.(2006). Ground water Occurance in Ethiopia.UNESCO.

Temitope D., Oyedotun, Opeyemi Obatoyinbo.(2012). Hydro-geochemical evaluation of groundwater quality in Akoko North West local government area of Ondo State, Nigeria. A & Av. 7(1): 67-80.

Toxicity in Broiler Breeders. Poultry Science 1997; (6):1493–1500.

UNICEF, 2008.Hand book on water quality. United Nations Children's Fund

Valerie Ndaruzaniye. (2011). Water Security in Ethiopia: Risks and Vulnerabilities Assessment.Global water Institute for Africa climate change, Environment and security Acces.

Vodela, J.K., J.A. Renden and S.D. Lenz. (1997). Drinking water contaminants. Michel Henney WH, Kemppainen BW,. Poult.: 76: 1474-1492.

Vodela.J, Lenz.S, Renden.A, Mcelheney.W and Kemppainen.B. Drinking Water Contaminants (Arsenic, Cadmium, Lead, Benzene, and Trichloroethylene) Effects on Reproductive Performance, Egg Quality, and Embryo

WHO (1984). Health criteria and other supporting information 101: 2

WHO (1997) Guidelines for drinking-water quality. Volume 3: Survilances and control of community suplies.World Health Organization,Geneva

WHO (2004) Guidelines for drinking-water quality, 3rd edn. World Health Organization,Geneva

WHO (2006).A guide line for drinking water quality first addendum to third edition Volume 1: Recommendations.

ZHANG H., (1990). Classification of Irrigation Water Quality. Oklahoma State

University Soil, Water and Forage Analytical Laboratory. Oklahoma Cooperative Extension, Factsheet PSS-2401-4.

Zodape G.,Dhawan V.,Wagh R. and Magare. (2013). Analysis of heavy metals and coliforms in samples of drinking water collected from manucipal ward offices of wesern suburbs and extended western suburbs of Mubai, India:6(2):252-259.

Annex1. Accepted level parameters and effect above accepted level

Measured parameters	**Acceptable level**	**Effect above/below level**
Total Dissolved Solids(TDS)	Max 1000	Stomach discomfort
Temperature	25°C	Bone disease(pain and tenderness of)children may get
Total Hardness	Max 500	Increase in blood pressure
Turbidity	Max 25	Nausea ,cramps, diarrhea and associated head ache
Calcium	Max 200mg/L	Indigestibility of fat in the body
Magnesium	Max 150mg/L	Gastro intestinal, liver or kidney damage
Potassium	Max 50mg/L	Effect on blood pressure
pH	6.5 - 8.5	Rusting, Cancer
Electrical Conductivity(EC)	Max	Anemia; liver kidney or spleen damage; changes in blood
Iron	0.3 mg/L	Rusting, Cancer
Sulfate	Max 400mg/L	Allergic dermatitis
Sodium	200mg/L	Increased risk of cancer

Annex 2. Measured physico-chemical parameters

S.N.	Sample Location	Temp(^{0}C)	EC (μS/cm)	PH	Turbidity (NTU)	TDS (mg/L)
AWSP1	Shebena	19.2	96.13	7.2	0.41	53.02
AWHP1	Tugri	20.7	231.4	5.92	0.41	126.3
AWHP2	Echi	23.5	197.8	6.31	0.89	107.9
YWHP1	Ermich	21.2	247.9	5.18	0.12	136.2
YWHP2	Kubito	22.4	238.1	6.68	0.45	131.5
YWSP1	Addis brihan	23.3	148.7	6.33	2.80	81.4
TTSP1	Andinet	24.1	186.9	6.5	0.14	103.6
TTSP2	Hibret	23.4	194	6.6	0.38	107.23
MWHP1	Keja	25.9	236	7.31	0.87	129.4
MWHP2	keja 2	26.2	104.3	7.85	0.63	57.7
MWHP3	Welo	25.8	175.4	7.13	0.41	97.3
MTHP1	Toba	28.8	116.8	6.26	0.72	64.3
MTHP2	Shuni	24.3	94.2	6.8	0.31	51.4
Minimum		19.20	94.20	5.18	0.12	51.40
Maximum		28.80	247.90	7.85	2.80	136.20
Mean		23.75	174.43	6.62	0.66	95.94
WHO (2004)		≤ 15	250	6.5-8.5	5	500
Ethiopian Standards		NA	NA	6.5-8.5	5	1,500

Annex 3.Measuresd chemical anion parameters

Site	TH	TA	HCO^{-}_{3}	CO_3^{2-}	Cl^-	SO_4^{2-}	NO_3-
AWSP1	38.00	38.40	36.4	0.00	3.14	14.08	0.82
AWHP1	45.00	29.70	32.3	0.00	0.14	22.4	1.95
AWHP2	35.00	31.00	28	0.00	3.41	16.4	1.82
YWHP1	25.00	24.00	31.5	0.00	1.12	18.09	1
YWHP2	27.00	30.00	36.4	0.00	2.14	16	0.41
YWSP1	24.00	42.00	15.9	0.00	2.96	15.4	0.61
TTSP1	18.00	20.00	14.2	0.00	1.19	39	2.23
TTSP2	18.00	17.00	41.3	0.00	0.98	8.24	1.39
MWHP1	55.00	47.00	16.9	0.00	3.13	14.4	11.4
MWHP2	25.00	39.20	24	0.00	3.61	24.1	1.53
MWHP3	75.00	49.00	54.3	0.00	2.81	41.3	0.86
MTHP1	60.00	36.40	37	0.00	1.16	32.8	1.4
MTHP2	39.00	47.00	41.6	0.00	2.74	9.87	0.41
Min	18.00	17.00	14.00	0.00	0.14	8.24	0.41
Max	75.00	49.00	54.30	0.00	3.61	41.30	11.40
Mean	37.23	34.67	31.52	0.00	2.19	20.93	1.99
WHO, 2004	200	100	200	NA	250	250	10
Eth. Std.	500	600	NA	NA	533	483	10

Annex 4

A) Field based activity

Field based measurement of non-conservative parameters

Recording GPS coordinates of sample sites

B) Laboratory base activities